Does Product Quality Signal Improve the Information Matching Efficiency of the Sponsored Search Auction Mechanism?

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Abstract: This article investigates the information matching efficiency of the sponsored auction mechanism of search engine platform by implementing consumer purchase strategy. Then we examine the incentive mechanism for sellers to report product quality truthfully under information asymmetry and the reason how product quality signal could improve information matching efficiency of the sponsored auction mechanism. Using the data collected from Baidu search engine, we empirically test the theoretical research results. Our main research finding: under information asymmetry and without product quality signal mechanism, the equilibrium of bidding rank cannot match the consumer purchase strategy at all, causing the consumer welfare to suffer double losses due to the adverse selection of sellers. In the contrast, the search engine could improve partially the information matching efficiency of the sponsored search auction mechanism by identifying the product quality signal brought by the sellers with the highest product quality. However, the search engine has no incentive to design product quality signal for sellers.

Keywords: bidding rank; information asymmetry; search engine; product quality

1. Introduction

The sponsored search auction mechanism refers to the process of bidding rank in which the sellers obtain the sponsored positions through bidding (Varian, 2007; Chen and He, 2011). Well-known search engine platforms, including Google, Bing and Baidu, arrange sponsored positions by the sponsored search auction mechanism. Furthermore, the sponsored search auction mechanism contributes billions of dollars for search engines platform (Chen and He, 2011). When a consumer clicks on sponsored link (also called the sponsored search results) each time, the seller occupying the corresponding sponsored position needs to pay biding amount to the search engine. Therefore, whether consumers could get the information they need in sponsored search results or not is about whether the sponsored search results could achieve information matching between the consumer and seller (Qu and Liu, 2019).

Recently, the information matching efficiency of the sponsored search auction mechanism is a research topic. Using the data of keyword auction results from search engines, Yang and Ghose (2010) empirically examine the differences in bidding behavior between sponsored and organic positions. Interestingly, they find that the click to buy ratio of the first three sponsored positions is about 3% less than that of the fourth to sixth organic positions but the fourth to sixth organic search results contribute more to the seller's profits than the sponsored search results at the top. Further evidence shows that experienced consumers are more likely to click on the organic search results in the middle and purchase (Baye et al., 2016). In other words, sellers who occupy sponsored positions hide product information from search engines. Essentially, there is information asymmetry between the seller and consumer. Obviously, there is also a problem of lemon market in the sponsored search auction market of search engines (Akerlof, 1970). Then we want to know: ①whether the sponsored search result matches the consumer information demand completely under information asymmetry? ② how to improve the information matching efficiency of the sponsored search auction mechanism? This paper will answer these questions.

The anecdotical evidences also show that information asymmetry is the common state of consumer information in real life, such as the case of Google penalty in the United States and the "Wei Zexi incident" in China. In August 2015, Google was fined $500 million for grabbing links

of medical service sellers who posted fake medical advertisements, and Google was ordered to delete related links[1]. Similarly, in May 2016, Wei Zexi, a college student in Shanxi Province of China, died after receiving fake treatment from a medical service seller after believing in sponsored search results for keyword searches by Baidu[2].Both incidents above clearly show that due to information asymmetry, the search engines recommend those sellers with hidden quality to consumers through the sponsored search auction mechanism, and consumers accept the recommendations of search engines and click on their paid search results.

However, the previous literature pays the research attention for the information efficiency of the sponsored search auction mechanism under the complete information. For an instance, Chen and He (2011) investigate the information efficiency of the sponsored search auction mechanism in the case of consumer continuous search. They find that if the search engine platforms are fully aware of the types of consumers' preferences and sellers' product information, they will usually put different types of sellers in the corresponding sponsored positions according to the order of consumer preferences when arranging the sponsored search results. In fact, as long as the search engine can fully know the information type of the users on both sides (that is, the complete information), the equilibrium result of the sponsored search auction mechanism will optimally match the information supply and demand of the users on both sides, even if consumer search behavior is heterogeneous and with significant information cost, and some consumers rely on the information intermediary role of search engines (Cheng and Zhang, 2011; Golrezaei and Nazerzadeh, 2017; Chen and Zhang, 2017).

In this work, we propose a comparative static analysis of the information matching efficiency of the sponsored search auction mechanism under different information states. First of all, we extend the theoretical model from Chen and He (2011), changing information state from complete information to asymmetric information. Under that condition, the search engine and consumer fail to know the true quality of the products sold by sellers. At the same time, sellers falsely report product quality to make the public believe that their products have high product quality, i.e. the adverse selection of sellers. Then, we examine the equilibrium of the sponsored search auction mechanism with four sponsored positions[3] and take the equilibrium in the state of complete information as the benchmark equilibrium. Thirdly, based on the signal theory in which market signals can alleviate the condition of information asymmetry (Spence,1973), we try to optimize the information matching efficiency under the sponsored search auction mechanism and information asymmetry by implementing product quality as a signal (named as product quality signal). Finally, using the data collected from Baidu search engine, we conduct Probit regression analysis to test the equilibrium of the theoretical model and explore the correctness and applicability of the theoretical research conclusions.

On the whole, our main finding: the sellers with highest nominal product quality in the sponsored search auction market are willing to build product quality signals to transmit product quality information to search engines in order to get high sponsored positions in keywords auction. That is, the product quality signal could partially improve the information matching efficiency of

[1]Source: citing a news report from the *Wall Street Journal*.

[2]For details, the joint investigation team of China Internet Network and the State Internet Information Office announced the results of the survey stationed in Baidu.com, http://www.cac.gov.cn/2016-05/09/c_1118833529.htm

[3]According to the requirements of the China National Network Information Office, the sponsored search results presented by the search engine firms shall not exceed 30% of the total number of search results per page. Based on the maximum of 15 search results per page, the maximum number of sponsored search results per page is

the sponsored search auction mechanism. Accordingly, the search engine could identify the product quality signal brought by the sellers but has no incentive to design product quality for the sellers. It also confirms that although Google claims to have formed a professional team to improve the way in which search results are crawled, it is still difficult for consumers to find clear differences among sponsored search results.

Section 2 presents the theoretical model and the theory of keywords auction under information symmetry. Section 3 derives the model without product quality signal and examines the consumer welfare effect under the sponsored search auction mechanism and information asymmetry on Internet. Section 4 is the derivation of the model under the product quality signal mechanism, and discusses how product quality signal improve the consumer effect under the sponsored search auction mechanism. Section 5 carries out an empirical test, and we combine the industrial practice data to test the conclusions of the models. Finally, section 6 summarizes the full text and put forward some suggestions.

2. Theoretical Model

2.1 Model set

Based on the analysis above, we consider the following assumptions for the search engine, sellers and consumers.

Firstly, we assume that the search engine implements the current auction mechanism. The essence of the current sponsored search auction mechanism is the Generalized Second Price (GSP) Auction. Its bidding process is that the equilibrium bid amount of each sponsored position is offered by the seller with the highest expectation of the sponsored position, and the bidder (seller) with the highest expectation is the executor of the bidding strategy (Edelman et al., 2007). Accordingly, the payment equilibrium is that the payment amount of the sponsored position is equal to the equilibrium bid amount of the next sponsored position. That is to say the amount b_i paid by the seller in the sponsored position S_i is the equilibrium bid amount B_{i+1} of the next sponsored position, namely$b_i = B_{i+1}$. And the amount b_4 that the seller in the sponsored position S_4 pays for is the bid amount B_k of the seller who is in the first position of the organic search results, namely $b_4 = B_k$.

Secondly, sellers need to set bidding strategies based on consumer preferences (the product quality). Therefore, we assume that the product quality is the only bidding strategy for sellers and the unit profit increases with the improvement of the product quality for each seller, namely $\pi'(\gamma_i) > 0$. $\pi(\gamma_i)$ is the profit per unit product of seller H_i, and γ_i is the product quality of seller H_i.

In addition, when consumers trust the keyword retrieval results presented by the search engine, the purchase strategy of consumers is that the probability of choosing sponsored search results will reduce with the sponsored positions decreasing (Chen and He, 2011; Chen and Zhang, 2017). Therefore, we assume that the probability p_n of consumers choosing sponsored search results has the following characteristic.

$$p_n = \sigma^{n-1}\beta,\ n = 1,2,3,4 \quad (1)$$

β is the probability of choosing the sponsored position S_1. And σ is a probability attenuation multiple, so $0 < \sigma < 1$. Once the sellers in the four sponsored positions have been arranged, there will be one seller out of the sponsored search results and arranged in the organic search results. Given that the seller, who is out of the sponsored search results, is also involved in the bidding, the search engine will arrange it in the first position S_k of the organic search results, so the

probability of being chosen by consumers is p_k, i.e. $p_k = \sigma^4\beta$. In addition to the five sellers participating in the keywords auction, other sellers also have opportunities to be selected by consumers, so the sum of the probability that the five sellers participating in the keywords auction can be selected is less than 1, i.e. $p_1 + p_2 + p_3 + p_4 + p_k \leq 1$. We deduce the constraint condition of σ $(0 < \sigma < \frac{1}{2})$ in order to reduce the strong limit to the probability β of consumers choosing the sponsored search results at the first time.

2.2 Model equilibrium

Under sufficient information of sellers, the search engine and consumers, we will discuss the equilibrium of bidding rank in two cases: One is that the product quality of sellers is different and another is that the product quality of sellers is all the same[4].

First of all, we examine the equilibrium of bidding rank under the condition that the product quality of sellers is different, and we calculate sponsored positions of sellers and their profits at equilibrium.

In order to facilitate the solution and keep the generality, we might as well assume that the sellers H_1 to H_4 and H_k participating in the keywords auction are listed in the sponsored positions S_1 to S_4 and the first position of organic search results S_k respectively. And the quality of their products is in descending order, namely $\gamma_1 > \gamma_2 > \gamma_3 > \gamma_4$.. We make different sorting combinations through moving the sponsored positions of sellers H_i $(i = 1, 2, 3, 4, k)$. Accordingly, the unit profits of sellers H_i are ranked as $\pi(\gamma_1) > \pi(\gamma_2) > \pi(\gamma_3) > \pi(\gamma_4) > \pi(\gamma_k) > 0$. Combined with the characteristics of bidding equilibrium of the sponsored search auction mechanism, we can know that the bid amount of the sponsored positions S_1 to S_4 is B_1^0 to B_4^0.

$$B_1^0 = \beta[\pi(\gamma_1) - \sigma\pi(\gamma_2) + \sigma^2\pi(\gamma_3) - \sigma^3\pi(\gamma_4) + \sigma^4\pi(\gamma_k)] \quad (2)$$

$$B_2^0 = \beta[\sigma\pi(\gamma_2) - \sigma^2\pi(\gamma_3) + \sigma^3\pi(\gamma_4) - \sigma^4\pi(\gamma_k)] \quad (3)$$

$$B_3^0 = \beta[\sigma^2\pi(\gamma_3) - \sigma^3\pi(\gamma_4) + \sigma^4\pi(\gamma_k)] \quad (4)$$

$$B_4^0 = \beta[\sigma^3\pi(\gamma_4) - \sigma^4\pi(\gamma_k)] \quad (5)$$

As $0 < \sigma < 1/2$ and $\pi(\gamma_1) > \pi(\gamma_2) > \pi(\gamma_3) > \pi(\gamma_4) > \pi(\gamma_k) > 0$, it can be deduced that $B_1^0 > B_2^0 > B_3^0 > B_4^0$, which means the bid amount decreases with the decline of the sponsored positions. Besides, B_1^0 to B_4^0 is the amount tendered by sellers H_1 to H_4. In fact, sellers H_k also participate in the bid, and their bid amount is their net profits, namely $B_k^0 = \pi_k^0 = \sigma^4\beta\pi(\gamma_k)$. The bid amount is the minimum amount for sellers H_k to obtain the sponsored positions. In this way, the bid amount of the sponsored positions S_1 to S_4 can be deduced in reverse, and the bid amount in other cases can also be deduced in this way.

According to the characteristics of the bidding equilibrium of the sponsored search auction mechanism, subtracting the seller's profit from the bid amount, we can obtain the net profits π_1^0 to π_4^0 of the sellers H_1 to H_4 in the sponsored positions S_1 to S_4.

$$\pi_1^0 = \beta[\pi(\gamma_1) - \sigma\pi(\gamma_2) + \sigma^2\pi(\gamma_3) - \sigma^3\pi(\gamma_4) + \sigma^4\pi(\gamma_k)] \quad (6)$$

$$\pi_2^0 = \beta[\sigma\pi(\gamma_2) - \sigma^2(\gamma_3) + \sigma^3(\gamma_4) - \sigma^4(\gamma_k)] \quad (7)$$

[4]We give upthe special case that there are two and more than twosellers with different products, as well as two and more than twosellers with the same product quality. Because this particular case is a different combination of the first two cases above.

$$\pi_3^0 = \beta[\sigma^2(\gamma_3) - \sigma^3(\gamma_4) + \sigma^4(\gamma_k)] \quad (8)$$

$$\pi_4^0 = \beta[\sigma^3(\gamma_4) - \sigma^4(\gamma_k)] \quad (9)$$

As $0 < \sigma < 1/2$ and $\pi(\gamma_1) > \pi(\gamma_2) > \pi(\gamma_3) > \pi(\gamma_4) > \pi(\gamma_k) > 0$, we can prove that $\pi_1^0 > \pi_2^0 > \pi_3^0 > \pi_4^0$, which means the sellers in high sponsored positions also have high net profits. As a result, the seller in a low sponsored position expects to move to a high sponsored position by increasing the bid amount. While the seller in low sponsored position moves to a high sponsored position, the seller in high sponsored position will move to allow sponsored position by reducing the bid amount, providing moving space for the seller in low sponsored position, with a new sorting combination forming. We will discuss the incentive effect of sellers moving sponsored positions on the basis of the descending order of their product quality.

There are several specific situations in which the sellers H_1 to H_4 in the sponsored positions S_1 to S_4 move to other sponsored positions. The seller H_4 in the sponsored positionS_4 can move to the high sponsored positions S_1, S_2 and S_3, without low sponsored positions to move to. The seller H_3 in the sponsored position S_3 can move to the high sponsored positions $S_1$and S_2 and the low sponsored position S_4.The seller H_2 in the sponsored position S_2 can move to the high sponsored position S_1 and the low sponsored positions S_3 and S_4.The seller H_1 in the sponsored position S_1 can move to the low sponsored positions S_2, S_3 and S_4, without high sponsored positions to move to. In addition, sellers H_k in the organic search results positions S_k can move to every sponsored position. We examine the incentives of sellers H_i $(i = 1, 2, 3, 4, k)$ to move sponsored positions each time[5].

In fact, the incentive effect of each seller moving to another sponsored position is consistent with the intuitive feeling. The sellers in low sponsored positions have strong incentives to move to high sponsored positions, while those in high sponsored positions have no incentive to move to low sponsored positions strictly. Specifically, the seller H_4 in the sponsored position S_4 has incentives to move to the high sponsored positions S_1, S_2 and S_3, and the incentive effect weakens as the sponsored position decreases. The seller H_3 in the sponsored position S_3 has incentives to move to the high sponsored positions S_1 and S_2, and the incentive effect weakens as the sponsored position decreases, without any incentive to move to the low sponsored position S_4. The seller H_2 in the sponsored position S_2 has incentives to move to the high sponsored position S_1, without any incentive to move to the low sponsored positions S_3 and S_4. The seller H_1 in the sponsored position S_1 has no incentive to move to the low sponsored position S_2, S_3 and S_4. Therefore, the sellers H_1 to H_4 of the descending order of the product quality cannot move their positions to form a new arrangement, which means that the descending order of the product quality is the only bidding equilibrium under information symmetry on both sides of the search engine. In addition, sellers H_k have strict incentives to enter the sponsored search results and move to high sponsored positions. And as the sponsored position rises, sellers H_k will get better incentive effect.

Secondly, we further investigate the bidding equilibrium under the condition that the seller's product quality is the same, and then calculate the sponsored positions and net profits of each seller when they are at the equilibrium.

Since the product quality of all sellers is the same, their bids for each given sponsored position S_n $(n = 1, 2, 3, 4)$ are also the same. Therefore, when the search engine arranges sellers

[5]We put the specific proof process, including some propositions, in the appendix.

with given sponsored positions, it has to adopt the random principle. Therefore, the sponsored search auction mechanism will transmit the information of the product quality to consumers according to the random principle, failing to reflect the no difference of sellers' product quality. Nevertheless, the sponsored search auction mechanism is still neutral on whether it can improve consumer welfare.

To sum up, we can see that under tripartite subject information symmetry, there will be two kinds of equilibrium in the sponsored search auction mechanism.① If the sellers' product quality is different, the search engine will arrange the sellers of the sponsored positions S_1 to S_4 in descending order of the product quality, and arrange the seller with the lowest product quality to the first position in the list of organic search results S_k. The net profits of sellers reduce with the decrease of the sponsored positions, and the seller who is in the first position S_k of the organic search results has the lowest net profit.② If the sellers' product quality is the same, the search engine will arrange sellers in the sponsored positions S_1 to S_4 and the first position of organic search results according to the random principle. And the net profit of each seller is random. Furthermore, we can get proposition 1.

Proposition 1: Under information symmetry, the search engine arranges the positions according to the descending order of product quality. The results of the keywords auction are exactly matched with the purchase strategy of consumers.

Proposition 1 reveals that the consumer welfare effect of the auction mechanism is optimal under information symmetry, consistent with the conclusion of Chen and He (2011).The bidding equilibrium ① is optimal for consumers, the search engine, and the sellers with the highest product quality. Consumers can make the best purchase decision according to the order of the sponsored positions of search results without worrying about the economic loss caused by sellers falsely reporting the product quality. Accordingly, the search engine maintains the monopoly position of the search market by consolidating the trust of consumers. In this way, the search engine proposes two choices to the sellers with low product quality including accepting the bidding equilibrium and withdrawing from the sponsored search auction mechanism. Therefore, only the sellers with the highest product quality are satisfied with the first sponsored position arranged by the search engine, while other sellers have incentives to seek for high sponsored positions. This is why sellers want to get high sponsored positions by falsely reporting their product quality. The bidding equilibrium②shows that even in the extreme cases, the sponsored search auction mechanism can still maintain neutrality to consumer welfare.

3. Model Derivation without Product Quality Signal Mechanism

When there is information asymmetry among the search engine, consumers and the sellers, the sellers as the information superior party can falsely report product quality to consumers and the search engine, i.e. the adverse selection of sellers. Because the search engine is the information inferior party, it will not take any measure and connives sellers to select adversely instead, damaging the welfare of consumers. The situation that the search engine takes no measure means there is no product quality signal mechanism. We will examine the seller bidding equilibrium without product quality signal mechanism, and discuss the consumer welfare effect under the sponsored search auction mechanism and information asymmetry and without product quality signal mechanism.

3.1 Adverse selection of sellers

It can be seen from proposition 1 that the incentives for sellers with different product quality

are different from those who falsely report product quality. We might as well assume that the product quality of sellers H_i $(i = 1, 2, 3, 4, k)$ decreases in turn, namely $\gamma_1 > \gamma_2 > \gamma_3 > \gamma_4 > \gamma_k$. First of all, when other sellers truthfully report product quality, the seller H_1 with the highest product quality has no incentive to falsely report product quality because it has occupied the first sponsored position S_1. Secondly, regardless of whether other sellers falsely report product quality or not, the sellers H_k, with the lowest the product quality, have incentives to falsely report product quality. There are two reasons. On the one hand, they expect to enter the list of sponsored search results, and on the other hand, they expect to get high sponsored positions. Thirdly, after sellers H_k falsely report product quality, the sellers H_2, H_3, and H_4 all have incentives to report product quality falsely in order to obtain high sponsored positions. Therefore, we will analyze the three cases of adverse selection of sellers. ①Only the seller H_k report product quality falsely. ② The sellersH_2, H_3, and H_4 and H_k report product quality falsely.③All sellers falsely report product quality.

3.2 Bidding equilibrium of sellers

In case①, the seller H_k will falsely report product quality to make the search engine treat it as the highest quality seller, and in this case $\gamma_k^1 > \gamma_1$. According to the analysis above, we know that the seller H_k will be arranged by the search engine in the first sponsored position S_1. Although the seller H_k can set the quality γ_k^1 of product falsely in the range (γ_4, γ_1), trying to occupy one of the sponsored positions S_2 to S_4, they still have incentives to occupy the first sponsored position S_1. Because the seller H_k can falsely report product quality to consumers and the search engine with a cost of zero. At this time, the sellers in the sponsored positions S_2 to S_4 are H_1, H_2 and H_3 respectively. Accordingly, the seller H_4 occupies the first position S_k of the organic search results. Combined with the bidding equilibrium characteristics of the sponsored search auction mechanism, the bid amount of the sponsored positions S_1 to S_4 is as follows.

$$B_1^1 = \beta[\pi(\gamma_k^1) - \sigma\pi(\gamma_1) + \sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)] \quad (10)$$

$$B_2^1 = \beta[\sigma\pi(\gamma_1) - \sigma^2\pi(\gamma_2) + \sigma^3\pi(\gamma_3) - \sigma^4\pi(\gamma_4)] \quad (11)$$

$$B_3^1 = \beta[\sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)] \quad (12)$$

$$B_4^1 = \beta[\sigma^3\pi(\gamma_3) - \sigma^4\pi(\gamma_4)] \quad (13)$$

As $\pi(\gamma_4) < \pi(\gamma_3) < \pi(\gamma_2) < \pi(\gamma_1) < \pi(\gamma_k^1)$ and $0 < \sigma < 1/2$, it can be deduced that $B_1^1 > B_2^1 > B_3^1 > B_4^1$, which means the bid amount decreases with the decline of the sponsored positions. In addition, B_1^1 to B_4^1 are tendered by the sellers H_k and H_1 and H_3, who want to get the sponsored positions S_1 to S_4 respectively. The seller H_4 also participate in the tender, and the tender amount is its net profit, namely $B_k^1 = \pi_4^k = \sigma^4\beta\pi(\gamma_4)$.

Combined with the characteristics of the bidding equilibrium of the sponsored search auction mechanism, we subtract the bid amount from the unit profits of sellers, deducing the net profits π_1^2, π_2^3, π_3^4 of the sellers H_1 to H_3 in the sponsored positions S_2 to S_4: $\pi_1^2 = \beta[\sigma\pi(\gamma_1) - \sigma^2\pi(\gamma_2) + \sigma^3\pi(\gamma_3) - \sigma^4\pi(\gamma_4)]$, $\pi_2^3 = \beta[\sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)]$, and $\pi_3^4 = \beta[\sigma^3\pi(\gamma_3) - \sigma^4\pi(\gamma_4)]$. As $\pi(\gamma_4) < \pi(\gamma_3) < \pi(\gamma_2) < \pi(\gamma_1)$ and $0 < \sigma < 1/2$, it can be proved that $\pi_1^2 > \pi_2^3 > \pi_3^4$, which means the net profits of the sellers H_1 to H_3 in the sponsored positions S_2 to S_4 decrease with the decline of the sponsored positions.

Different from other sellers, the seller H_1, who falsely reports product quality, has two choices. The seller H_1 can choose to continue to hide the real product quality from consumers, charging the price p_f of product whose quality is γ_k^1 and getting unit profit $\pi(\gamma_k^1)$. The seller H_1

can also choose to confess to consumers that they can only provide the products whose quality is γ_k, charging the price p_t and getting unit profit $\pi(\gamma_k)$. Under the first option, the net profit of the seller H_1 is $(\pi_k^1)_1$.

$$(\pi_k^1)_1 = \beta[\pi(\gamma_k^1) - \sigma\pi(\gamma_1) + \sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)] \quad (14)$$

As $\pi(\gamma_4) < \pi(\gamma_3) < \pi(\gamma_2) < \pi(\gamma_1) < \pi(\gamma_k^1)$ and $0 < \sigma < 1/2$, it can be deduced that $(\pi_k^1)_1 > \pi_1^2$. It indicates that sellers can make huge profits by falsely reporting the product quality, while consumers pay the cost but get the products whose quality is γ_k. Under that condition, consumers would suffer two kinds of welfare losses. One is the difference between the expected product quality and the real product quality, which results in the loss of utility in use. Another is that the product whose quality is γ_k pays the excess price, $p_f - p_t$, resulting in economic losses. In the second case, the net profit of the seller H_k is $(\pi_k^1)_2$.

$$(\pi_k^1)_2 = \beta[\pi(\gamma_k) - \sigma\pi(\gamma_1) + \sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)] \quad (15)$$

If $(\pi_k^1)_2 > 0$, then $\pi(\gamma_k) > \left(\sigma\pi(\gamma_1) - \sigma^2\pi(\gamma_2) + \sigma^3\pi(\gamma_3) - \sigma^4\pi(\gamma_4)\right)$. Because $\pi(\gamma_4) < \pi(\gamma_3) < \pi(\gamma_2) < \pi(\gamma_1)$ and $\pi(\gamma_k) > \sigma\pi(\gamma_2)(1-\sigma) + \sigma^3\pi(\gamma_4)(1-\sigma) > \pi(\gamma_4)(\sigma+\sigma^3)(1-\sigma)$. By relaxing and tightening constraints, we can know that if the inequality, $\pi(\gamma_4)(\sigma+\sigma^3)(1-\sigma) < \pi(\gamma_k) < \pi(\gamma_4)$, is satisfied, sellers can still make positive profits by confessing and providing consumers with their real product quality. Consumers suffer only one kind of welfare loss, which is the difference between the expected product quality and the real product quality. $(\pi_k^1)_2 < 0$ while $\pi(\gamma_k) < \pi(\gamma_4)(\sigma+\sigma^3)(1-\sigma)$, indicating that the seller H_k is at risk of economic loss. Furthermore, the seller H_k has strong incentives to continue to conceal the true product quality in order to avoid risk. Therefore, the optimal decision of the seller H_k is to falsely report product quality and continue to conceal it.

It is not difficult for us to find the equilibrium of bidding rank in case①. The search engine arranges the seller H_k who falsely reports product quality in the first sponsored position S_1, and arranges the sellers H_1 to H_4 in the sponsored positions S_2 to S_4 and the first position S_k of the organic search results in descending order of product quality. The optimal decision of the seller H_k is to continue to conceal the real product quality, and its net profit is higher than that of the seller H_1. It shows that only when the seller H_k select adversely, can the keywords auction results match the purchase strategy of consumers partially. In other words, excepting for the seller H_k, other sellers who truthfully report their product quality are listed in the sponsored positions and the first position of organic search results according to the descending order of product quality. The reason why the seller H_k choose to continue to conceal the real product quality is not only about the risk aversion, there may be another reason. If sellers confess to consumers and charges the price p_{ture}, consumers will doubt the product quality after receiving goods, even propose the quality appraisal and ask for compensation. As a result, the sellers will face economic losses and reputation losses. However, there is an exception. Consumers themselves expect to buy cheap knockoffs, and the seller choices of confession would be viable strategies, but still be suboptimal strategies. Although sellers are the superior parties of information, it is impossible to understand the preferences of every consumer. We can learn from the later analysis that not only the seller H_k with the lowest product quality, but other sellers will also choose to hide after falsely reporting product quality.

In case②, all the sellers $H_j(j = 2,3,4,k)$ expect that their false product quality can exceed that of others in order to obtain the first sponsored position S_1, so the product quality that they

claim is the upper limit of their product quality. That is, $\gamma_h(\gamma_h > \gamma_k^1 > \gamma_1)$, and sellers H_j participate in keywords auction in that method. Therefore, only the seller H_1truthfully reports product quality and bids for the access to the list of sponsored results. According to the bidding equilibrium characteristics of the sponsored search auction mechanism, we can know that the bid amount B_1^2 to B_4^2 of the sponsored positions S_1 to S_4 is as follows.

$$B_1^2 = \beta[\pi(\gamma_h) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_1)] \quad (16)$$

$$B_2^2 = \beta[\sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_1)] \quad (17)$$

$$B_3^2 = \beta[\sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_1)] \quad (18)$$

$$B_4^2 = \beta[\sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_1)] \quad (19)$$

As $\pi(\gamma_h) > \pi(\gamma_1)$ and $0 < \sigma < 1/2$, it can be deduced that $B_1^2 > B_2^2 > B_3^2 > B_4^2$, which means the bid amount decreases with the decline of the sponsored positions. Furthermore, according to the analysis above, because sellers H_j have the same product quality, bid amount for the sponsored position is exactly the same. The bid amount shown in formulas (16) to (19) is not tendered by a certain seller. Therefore, the search engine arranges sellers H_j in the sponsored positions S_1 to S_4 according to the random principle. In addition, the seller H_1 also participate in the keywords auction, and bid amount is the net profit, namely $B_k^2 = \pi_1^k = \sigma^4\beta\pi(\gamma_1)$. Then the seller H_1 will be arranged at the first position S_k of organic search results.

Accordingly, excepting for the seller H_1, sellers H_j have two options: concealment and confession. Through derivation of the model (see appendix for the specific process), the optimal strategy of sellers H_j is to continue to conceal the real product quality from consumers. It's not difficult to find the equilibrium of bidding rank in case ②. The search engine arranges sellers H_j to the sponsored positions S_1 to S_4 according to the random principle, and arranges the seller H_1 in the first position S_k of the organic search results. The optimal strategy of sellers H_j is to continue to conceal the real product quality from consumers, and their net profits is random, but higher than that of the seller H_1. The equilibrium of bidding rank of case② shows that when only the seller H_1 reports the real product quality, the results of the keywords auction do not match the purchase strategy of consumers at all.

In case③, all of the sellers $H_i(i = 1,2,3,4,k)$ will falsely report product quality γ_h and take it as a bidding strategy to participate in keywords auction to compete for the first sponsored position S_1. According to the bidding equilibrium characteristics of the sponsored search auction mechanism, we can know that the bid amount B_1^3 to B_4^3 of the sponsored positions S_1 to S_4 is as follows.

$$B_1^3 = \beta[\pi(\gamma_h) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)] \quad (20)$$

$$B_2^3 = \beta[\sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)] \quad (21)$$

$$B_3^3 = \beta[\sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)] \quad (22)$$

$$B_4^3 = \beta[\sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)] \quad (23)$$

As $0 < \sigma < 1/2$, it can be deduced that $B_1^3 > B_2^3 > B_3^3 > B_4^3$, which shows that the bid amount decreases with the decline of the sponsored positions. What's more, according to the previous analysis, because sellers H_i have the same product quality, their bid amount is exactly the same. The bid amount shown in formulas (20) to (23) is not tendered by a certain seller. Therefore, according to the random principle, the search engine arranges sellers H_i in the

sponsored positions S_1 to S_4 and the first position of the organic search results S_k.

Accordingly, all the sellers H_i face two options: concealment and confession. When sellers H_i choose to conceal and are arranged to the sponsored positions S_1, S_2, S_3 and S_4, their net profits $(\pi_i^1)_1$ to $(\pi_i^4)_1$ are $(\pi_i^1)_1 = \beta[\pi(\gamma_h) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)]$, $(\pi_i^2)_1 = \beta[\sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)]$, $(\pi_i^3)_1 = \beta[\sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)]$, $(\pi_i^4)_1 = \beta[\sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)]$. respectively. Among them, as $0 < \sigma < 1/2$, it can be deduced that $(\pi_i^1)_1 > (\pi_i^2)_1 > (\pi_i^3)_1 > (\pi_i^4)_1 > 0$, which shows that the profit of the seller H_1decreases with the decline of the sponsored positions. It also shows that in the case of falsely reporting the product quality, every seller has incentives to compete for the sponsored positionS_1 without worrying about economic loss by paying a high bid amount. If every seller chooses to confess to consumers and is randomly assigned to the sponsored positionsS_2, S_3 andS_4 by the search engine, their net profits $(\pi_i^1)_2$ to $(\pi_i^4)_2$ are $(\pi_i^1)_2 = \beta[\pi(\gamma_i) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)]$, $(\pi_i^2)_2 = \beta[\sigma\pi(\gamma_i) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)]$, $(\pi_i^3)_2 = \beta[\sigma^2\pi(\gamma_i) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)]$, and $(\pi_i^4)_2 = \beta[\sigma^3\pi(\gamma_i) - \sigma^4\pi(\gamma_h)]$ respectively. Among them, if $(\pi_i^1)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\frac{\pi(\gamma_i)}{\pi(\gamma_h)} > (\sigma - \sigma^2 + \sigma^3 - \sigma^4)$. Name the above constraint condition as "constraint condition (1)". If $(\pi_i^2)_2 > 0$, the constraint condition of $\pi(\gamma_i)$is $\frac{\pi(\gamma_i)}{\pi(\gamma_h)} > (\sigma - \sigma^2 + \sigma^3)$. Name the above constraint condition as "constraint condition (2)". If $(\pi_i^3)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\frac{\pi(\gamma_i)}{\pi(\gamma_h)} > (\sigma - \sigma^2)$. Name the above constraint condition as "constraint condition (3)". If $(\pi_i^4)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\frac{\pi(\gamma_i)}{\pi(\gamma_h)} > \sigma$. Name the above constraint condition as "constraint condition (4)". It's easy to find that the constraint condition (2) is stricter than the constraint condition (1) and (3). Therefore, under constraint (2) and (4), sellers H_i choose to confess to consumers. Under other conditions, sellers H_i have no incentive to confess to consumers but chose to continue to conceal the real product quality. But the constraint condition (2) and (4) both are strong constraint conditions. Under those two conditions, sellers H_i are not only required to understand the attenuation multiple σ that consumers choose the next sponsored search result, that is, the type of consumers, they also need to improve their real product quality. But it's almost impossible. The optimal strategy for sellers H_i is to continue to conceal.

It is not difficult for us to find the equilibrium of bidding rank in case③. The search engine arranges sellers H_i in the sponsored positions S_1 to S_4 and the first position of the organic search results according to the random principle. The optimal strategy of sellers H_i is to continue to conceal their real product quality, and their net profits is at random. It reflects that when all sellers select adversely, the equilibrium of bidding rank does not match the purchase strategy of consumers at all. That is because the sponsored search auction mechanism can no longer convey any true information about product quality to consumers.

To sum up, we can know that under information asymmetry and without product quality

signal, all the three cases have bidding equilibrium, but they are not all Nash equilibrium under information asymmetry and without product quality signal. Continuing to analysis, we can deduce that the joint profit of sellers H_i in case① is lower than that of case②, and the joint profit of sellers H_i in case③ is lower than that of case②.Therefore, the equilibrium of case② is Nash equilibrium under information asymmetry and without product quality signal. As a result, proposition 2 is obtained.

Proposition 2: Under information asymmetry and without product quality signal, the equilibrium result of the keywords auction does not match the purchase strategy of consumers at all, and the consumer welfare effect of the auction mechanism is the weakest.

Proposition 2 reveals that under information asymmetry and without product quality signal, only the seller H_1 reports the product quality truthfully, however, other sellers select adversely. Due to the lack of product quality signal, the equilibrium of bidding rank result does not neither include the sellers with the first product quality nor help consumers to identify the real product quality of sellers. Accordingly, consumers face more welfare losses. As the number of searches and purchases increases, they will identify and judge which sellers in the list of sponsored search results are not trustworthy, and may stop buying on the search engine. As a result, the search engine will lose the trust of consumers.

It should be pointed out that although the equilibrium of bidding rank of case① and ③are not Nash equilibrium under information asymmetry and without product quality signal, however, it can help to analyze the necessity and feasibility of implanting product quality signal under information asymmetry. We can see from Table 1.

Table 1 Information matching efficiency of keywords auction under information asymmetry

The case number	Sellers select adversely	Bidding equilibrium	The degree of matching with the purchase strategy of consumers
①	Only the seller H_k	The seller H_k in the sponsored position S_1, the sellers H_1 to H_3 in the sponsored positions S_2 to S_4	Partially matching
②	Sellers H_2, H_3, H_4 and H_k	Sellers $H_j(j=2,3,4,k)$ randomly distribute in the sponsored positions S_1 to S_4	Completely mismatching
③	Sellers H_1, H_2, H_3, H_4 and H_k	Sellers $H_i(i=1,2,3,4,k)$ randomly distribute in the sponsored positions S_1 to S_4	Completely mismatching

Source: drawn by author.

In Table 1, sellers $H_j(j=2,3,4,k)$ with low product quality have more incentives to falsely report product quality than the seller with the first product quality. If the seller H_1 can transmit the information about the product quality to the search engine through the product quality signal mechanism, the seller H_1 can be listed in the sponsored search results and even obtain the first sponsored position S_1 in the case of other sellers select adversely. Then the seller H_1 can improve the matching degree between the equilibrium result of the keywords auction and the purchase strategy of consumers, so as to improve the welfare of consumers. Next, we will analyze

the existence and feasibility of the product quality signal mechanism.

4. Model Derivation under the Product Quality Signal Mechanism

In general, the search engine will take two measures to response. Firstly, the search engine designs product quality signal and identifies product quality signal for sellers to alleviate the impact of adverse selection on consumer welfare. Accordingly, the search engine first judges whether the product quality signal can improve its own profit, and then weighs whether to design the product quality signal for sellers[6]. What's more, the search engine can also place the sellers with high product quality in high sponsored positions by identifying the product quality signal brought by sellers, such as whether the seller's product is a well-known brand. Therefore, the search engine can improve the matching degree between the equilibrium of bidding rank and the purchase strategy of consumers, and then improve consumer welfare[7].Therefore, we investigate the two measures that the search engine can adopt. They are the introduction of product quality signal mechanism and the identification of seller product quality signal incentive effect. Through the investigation, we discuss the seller bidding equilibrium under the product quality signal mechanism, and then analyze the consumer welfare effect under the product quality signal mechanism.

4.1 Implementing the product quality signal mechanism into the search engine

Regardless of whether the seller is in adverse selection or not, the monopoly profit of the search engine is equal to the sum of the amount paid by the sellers in the sponsored positions. When only sellers H_k select adversely, the monopoly profit of the search engine is π_E^1: $\pi_E^1 = b_t^1 = \beta[\sigma\pi(\gamma_1) + \sigma^3\pi(\gamma_3)]$, of which b_t^1 is the sum of the amount paid by sellers H_1 to H_3 and H_k in case①. When sellers H_2, H_3, H_4 and H_k all select adversely, the monopoly profit of the search engine is π_E^2: $\pi_E^2 = b_t^2 = \beta[\sigma\pi(\gamma_h) + \sigma^3\pi(\gamma_h)]$, of which b_t^2 is the sum of the amount paid by sellers H_2 to H_4 and H_k in case②.After the search engine designs the product quality signal for sellers, the sellers H_1 to H_4 will truthfully report product quality. Compared to the situation where there is no product quality signal, the profit difference $\Delta\pi_E^1$ of the search engine is as follow.

$$\Delta\pi_E^1 = \pi_E^1 - \pi_E^2 = \beta\left[\sigma\left(\pi(\gamma_1) - \sigma\pi(\gamma_h)\right) + \sigma^3\left(\pi(\gamma_3) - \pi(\gamma_h)\right)\right] \quad (24)$$

As $\pi(\gamma_1) < \pi(\gamma_h)$ and $\pi(\gamma_3) < \pi(\gamma_h)$, then $\Delta\pi_E^1 < 0$, which shows that the product quality signal reduces the monopoly profit of the search engine. Therefore, the search engine has no incentive to establish a signaling mechanism to promote the sellers H_2 to H_4 to report truthfully product quality. When all sellers select adversely, the monopoly profit of the search engine is π_E^3: $\pi_E^3 = b_t^3 = \beta[\sigma\pi(\gamma_h) + \sigma^3\pi(\gamma_h)]$, of which b_t^3 is the sum of the amount paid by the sellers H_1 to H_4 in the sponsored positions S_1 to S_4 in case③.After the search engine designs a weak product quality signal for sellers, only the seller H_1 truthfully report product quality. Compared to the situation where there is no product quality signal, the profit difference $\Delta\pi_E^2$ of the search

[6] In fact, the third-party platform can benefit from the product quality signal.Using the data of American P2P lending platform (Prosper.com), Lin et al(2013)make an empirical analysis and find that theproduct quality signal attract more fund-raisers and investors to access the lending platform by improving the transaction efficiency of both sides, and then promote the rapid growth of the third-party platform.

[7] For example, in the job market, employers can decide whether to hire and offer the appropriate level of position and salary by identifying product quality signal such as the educational level and content of the job seeker, the fresh graduates (Bedard，2001).In this way, the mismatch rate between employees' wages and their abilities can be reduced.

engine is as follow.

$$\Delta\pi_E^2 = \pi_E^2 - \pi_E^3 = \beta\left[\sigma\left(\pi(\gamma_h) - \sigma\pi(\gamma_h)\right) + \sigma^3\left(\pi(\gamma_h) - \pi(\gamma_h)\right)\right] = 0 \quad (25)$$

Formula (25) indicates that the weak product quality signal still fails to improve the monopoly profit of the search engine. Summing up the above analysis, we can get proposition 3.

Proposition 3: When the information among sellers, the search engine and consumers is asymmetric, the search engine has no incentive to design product quality signal actively to encourage sellers to report product quality truthfully.

Proposition 3 shows that when the search engine has enough consumers, the search engine focuses on the monopoly profit rather than consumer welfare, that is, the incentive of consumer welfare is inconsistent with the monopoly profit of the search engine. The Baidu reputation built by Baidu Search is one of the examples. Although Baidu reputation certification has been online for 15 years, it has not played a significant role in reflecting the product quality of sellers. In contrast, the users (the sellers) of Baidu reputation certification have a lot of criticism about it. On the one hand, Baidu reputation certification is generally passive authentication rather than active authentication. Only after sellers put forward the authentication application, and pay the authentication fee, Baidu Search starts to verify the management condition and the reputation of the sellers. On the other hand, if sellers upgrade and continue to use Baidu reputation certification level, they need to continue to pay annual fees. The following empirical analysis will confirm this point of view.

4.2 The search engine identifies the seller's product quality signal

If the search engine can identify the product quality signal brought by sellers, the sellers will have the incentive to obtain the product quality signal, such as selling well-known brands familiar to consumers. However, there are differences in incentives for sellers to get product quality signal. When the sellers H_2 to H_4 obtain the product quality signal, the sellers H_2 to H_4 will be distinguished from sellers H_k, i.e. case①. If we want to explore the incentive effect of the sellers H_2 to H_4 to obtain product quality signal, we need to analyze the changes of the joint profit of the sellers H_2 to H_4 and sellers H_k before and after distinguishing the sellers H_2 to H_4 and seller H_k. In case ①, the joint profit of the sellers H_2 to H_4 and sellers H_k is π_j^1: $\pi_j^1 = \beta[\pi(\gamma_k^1) - \sigma\pi(\gamma_1) + 2\sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)]$. When the sellers H_2 to H_4 and sellers H_k falsely report the quality of their products, i.e. case②, the joint profit of the sellers H_2 to H_4 and sellers H_k is π_j^2: $\pi_j^2 = \beta[\pi(\gamma_h) - \sigma^4\pi(\gamma_1)]$. It is not difficult to find the difference in joint profits before and after they get the product quality signal of the sellers H_2 to H_4 and seller H_k is $\Delta\pi_j^1$.

$$\Delta\pi_j^1 = \pi_j^1 - \pi_j^2 = -\beta\left[\left(\pi(\gamma_h) - \pi(\gamma_k^1)\right) + \sigma\pi(\gamma_1) - 2\sigma^2\pi(\gamma_2) + \sigma^3\pi(\gamma_3) - \sigma^4\left(\pi(\gamma_1) + 2\pi(\gamma_4)\right)\right] \quad (26)$$

As $\pi(\gamma_4) < \pi(\gamma_3) < \pi(\gamma_2) < \pi(\gamma_1) < \pi(\gamma_k^1) < \pi(\gamma_h)$ and $0 < \sigma < 1/2$, through simulation we can know that when the difference in the unit profit of the sellers is small, in other words, when the market competition is more fierce, $\Delta\pi_j^1 < 0$. Therefore, in order to avoid risk, the sellers H_2 to H_4 have no incentive to obtain product quality signal.

We continue to analyze the incentive effect of the seller H_1 to obtain product quality signal. After the seller H_1 gets product quality signal, it will be distinguished from the sellers H_2 to H_4 and sellers H_k, consistent with case②.If we want to judge whether the seller H_1 has incentives

to get product quality signal, we need to analyze the changes of the joint profit of sellers $H_i(i = 1,2,3,4,k)$ before and after distinguishing the sellers H_2 to H_4 and seller H_k. In case ②, the joint profit of sellers H_i is π_m^2: $\pi_m^2 = \beta[\pi(\gamma_h) + \sigma^2\pi(\gamma_h) + \sigma^4\pi(\gamma_4)]$. When sellers H_i falsely report the quality of their products, i.e. in case ③, the joint profit of sellers H_i is π_m^3: $\pi_m^3 = \beta[\pi(\gamma_h) + \sigma^2\pi(\gamma_h)]$. It is not difficult for us to deduce that the difference in joint profit before and after they get the product quality signal of sellers H_i is $\Delta\pi_m^2$.

$$\Delta\pi_m^2 = \pi_m^2 - \pi_m^3 = \sigma^4\beta\pi(\gamma_4) \quad (27)$$

As $\pi(\gamma_4) > 0$, then $\Delta\pi_m^2 = \sigma^4\beta\pi(\gamma_4) > 0$. As a result, when the seller H_1 gets product quality signal, the joint profit of sellers H_i will increase. As a result, the seller H_1 has incentives to obtain product quality signal.

After the sellers H_2 to H_4 and sellers H_k occupy the sponsored positions by falsely reporting the product quality, the seller H_1 transmits the product quality information to the search engine and obtains the recognition with the help of product quality signal, such as whether the product sold is a well-known brand. It further reveals that other sellers falsely report product quality, so the seller H_1 is arranged to the first sponsored position S_1. In order to analyze the mechanism of the product quality signal, we assume that the seller H_1 has the product quality signal a and its product quality is γ_1, and the seller H_1 compete for keywords auction with the sellers H_2 to H_4 and sellers H_k who falsely report their product quality. First of all, we explore the bid amount $B_{1,j}$ to $B_{4,j}$ for sponsored positions S_1 to S_4 by one of the sellers $H_j(j = 2,3,4,k)$: $B_{1,j} = \beta[\pi(\gamma_h) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)]$; $B_{2,j} = \beta[\sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)]$; $B_{3,j} = \beta[\sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)]$; $B_{4,j} = \beta[\sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_h)]$. Secondly, we can easily deduce the bid amount $B_{1,a}$ to $B_{4,a}$ for the sponsored positions of the seller H_1 : $B_{1,a} = \beta[\pi(\gamma_1) - \sigma\pi(\gamma_1) + \sigma^2\pi(\gamma_1) - \sigma^3\pi(\gamma_1) + \sigma^4\pi(\gamma_1)]$; $B_{2,a} = \beta[\sigma\pi(\gamma_1) - \sigma^2\pi(\gamma_1) + \sigma^3\pi(\gamma_1) - \sigma^4\pi(\gamma_1)]$; $B_{3,a} = \beta[\sigma^2\pi(\gamma_1) - \sigma^3\pi(\gamma_1) + \sigma^4\pi(\gamma_1)]$; $B_{4,a} = \beta[\sigma^3\pi(\gamma_1) - \sigma^4\pi(\gamma_1)]$. Subtracting the bid amount of the seller H_1 from the bid amount of the sponsored positions of sellers H_j, we can get follow equations.

$$B_{1,a} - B_{1,j} = \beta\big(\pi(\gamma_1) - \pi(\gamma_h)\big)(1 - \sigma + \sigma^2 - \sigma^3 + \sigma^4) \quad (28)$$

$$B_{2,a} - B_{2,j} = \beta\big(\pi(\gamma_1) - \pi(\gamma_h)\big)(\sigma - \sigma^2 + \sigma^3 - \sigma^4) \quad (29)$$

$$B_{3,a} - B_{3,j} = \beta\big(\pi(\gamma_1) - \pi(\gamma_h)\big)(\sigma^2 - \sigma^3 + \sigma^4) \quad (30)$$

$$B_{4,a} - B_{4,j} = \beta\big(\pi(\gamma_1) - \pi(\gamma_h)\big)(\sigma^3 - \sigma^4) \quad (31)$$

As $\pi(\gamma_1) < (\gamma_h)$, then $B_{1,a} - B_{1,j} < 0$; $B_{2,a} - B_{2,j} < 0$; $B_{3,a} - B_{3,j} < 0$; $B_{4,a} - B_{4,j} < 0$, which shows that if the search engine only take the bid amount as a reference, it is unable for the seller H_1 to be listed in the sponsored search results. Obviously, after identifying the product quality signal of the seller H_1, the search engine decides to include the seller H_1 in the list of sponsored search results. When arranged at the first sponsored position S_1, the seller H_1 has to pay $b_{1,a}$: $b_{1,a} = B_{2,i}$. Accordingly, its net profit is $\pi_{1,a}$.

$$\pi_{1,a} = \beta\big(\pi(\gamma_1) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_h)\big) \quad (32)$$

If $\frac{\pi(\gamma_1)}{\pi(\gamma_h)} > (\sigma - \sigma^2 + \sigma^3 - \sigma^4)$, then $\pi_{1,a} > 0$, which shows that the seller H_1 obtains the first sponsored position S_1 and get normal profit by utilizing product quality signal. If $\frac{\pi(\gamma_1)}{\pi(\gamma_h)} < (\sigma - \sigma^2 + \sigma^3 - \sigma^4)$, then $\pi_{1,a} < 0$, which shows that the seller H_1 has no incentive to utilize

the product quality signal to get the first sponsored position S_1, and will be arranged at another sponsored position by the search engine according to random principle.

To sum up, we can know that in the case of the search engine identifying the seller product quality signal, there are two kinds of equilibria of the keywords auction. ①If $\frac{\pi(\gamma_1)}{\pi(\gamma_h)} > (\sigma - \sigma^2 + \sigma^3 - \sigma^4)$, the seller H_1 will obtain the first sponsored position S_1, and sellers $H_j(j = 2,3,4,k)$ will occupy the sponsored positions S_2 to S_4 and the first position S_k of organic search results according to random principle. ②If $\frac{\pi(\gamma_1)}{\pi(\gamma_h)} < (\sigma - \sigma^2 + \sigma^3 - \sigma^4)$, the seller H_1 will give up the first sponsored position S_1 actively and be arranged at other sponsored positions by the search engine according to random principle. And we can get proposition 4.

Proposition 4: Under information asymmetry, the search engine can match the equilibrium result of the keywords auction with the consumer purchase strategy partially by identifying the seller product quality signal. Compared to the situation where there is no product quality signal, the consumer welfare effect under the sponsored search auction mechanism can be partially improved.

Proposition 4 shows that the seller product quality signal can improve the matching degree between the equilibrium result of the keywords auction and the purchase strategy of consumers, realizing the shift from complete mismatching in case ② to partially matching. There are three cases in which the sponsored positions can match the consumer purchase strategy.①The sponsored positions S_1 to S_2 can match the consumer purchase strategy.②The sponsored positions S_2 to S_3 can match the consumer purchase strategy.③The sponsored positions S_3 to S_4 can match the consumer purchase strategy. Because the seller H_1 will not reduce the bid amount when it obtains the first sponsored position S_1, the monopoly profit of the search engine is still π_E^2, i.e. the monopoly profit in case ②.It makes the profit pursuit of the search engine consistent with the welfare pursuit of consumers, and then enables the search engine to include the seller H_1 in the sponsored search results and even the first sponsored position by identifying its product quality signal. However, while the seller H_1 gets the first sponsored position S_1, the search engine may also arrange other sellers to the sponsored position S_1. The seller H_1 may abandon the first sponsored positionS_1 due to the difficulty of affording the payment. In fact, that is the performance of the multi-equilibrium of the signaling game.

5. Empirical Analysis

5.1 Empirical design

Product quality signals selected in this work are the two types: the product quality signal designed by the search engine and the seller's own product quality signal. Generally speaking, reputation certification and reputation accumulation are product quality signals designed for sellers by the search engine. Reputation certification refers to that sellers apply for real name authentication to the search engine to obtain the certification rating of the search engine, in order to clarify the authenticity, compliance and legitimacy of their business activities. Reputation accumulation refers to the duration of cooperation between the sellers, who pass reputation certification, and the search engine. Previous studies have shown that the value of reputation lies in confirming the quality and reliability of the products sold by sellers. Consumers believe that the seller's information about the product sold is true and determines whether the product quality sold

is true through the reputation signal (Zhou et al., 2006).Similarly, the higher the reputation certification level is and the longer the reputation accumulation is, the more the search engine believes in product quality of sellers. Therefore, it is feasible for the search engine to implement the seller's reputation certification level and reputation accumulation as the product quality signals. The product quality signal of sellers is that whether the products sold are brands of well-known manufacturers, in order to show the superiority of the quality of their products to consumers and the search engine[8]. The reason is that in real life, where information is rich but consumers' attention is very limited, consumers are more likely to judge whether the products sold by sellers are well-known brands (Kahneman,1973). Specifically, ①of all the indicators that can represent either the unilateral performance or the comprehensive performance of a product, the information conveyed by the product brand is easier to understand. In other words, product brand is more attractive to consumers (Thorngate, 1990).②When the product brand presents the keywords auction results on the search engine, it is more convenient to express it in words and images, and it is easy to be perceived by consumers (Lanham, 2006).Similarly, it is feasible to use product brand as product quality signal.

In general, there are three ways for sellers to choose to sell well-known brands. Firstly, the sellers themselves are the online official malls of well-known brand manufacturers, such as Haier official mall. The reputation certification level of Haier official mall in Baidu Search is "V_3", and its duration of cooperation (reputation accumulation) is 93 months. All the products sold in the Haier's official mall are Haier's brand products. Secondly, the sellers cooperate with well-known brand manufacturers to build official flagship stores, such as the Haier official flagship store in Tmall Mall. Thirdly, the sellers and their merchants build tripartite franchise stores with well-known brand manufacturers, such as the Tmall Mall Haier Kecheng store.

Table 2 Indicators of all variables and their implications

Variables	Indicators	Meaning and description of indicators
S_1	Binary variables	If the seller wins the bid for the first sponsored position of a set of keywords auction, then $S_1 = 1$, otherwise $S_1 = 0$; The rule are as follows. In a set of keyword searches, the seller who appears the most frequently in the first sponsored position wins.If the number of appearances of the two sellers is tied for the first position, both sellers are winners. When all sellers appear equally, all of them are winners.
$Signal\_B$	Real name certification level *Id*_1	The seller's real name certification level is divided into three levels, which are V_1, $V_2$and V_3.V_1 and $V_2$are light blue marks, and$V_3$is golden yellow mark. If the seller's real name certification level isV_1/V_2, *Id*_1=0; if the seller's real name certification level is V_3, then *Id*_1=1.
	Duration of cooperation	Add 1 to the length of duration of cooperation and take the

[8]We determine the list of well-known brands in a certain industry in the way of information comparison. First of all, query the last year's product sales list or product awareness list in a given industry through Baidu search and other search engine platforms to determine the candidate list of well-known brands. Then, consult the candidate brand network word of mouth through Baidu Encyclopedia, Baidu Know and other basic knowledge introduction platforms to further determine the specific list of well-known brands.

	*Tim*_1	logarithm of it. The minimum duration some sellers work with the search engine is one month, and if we take the logarithm directly, we will get the value of 0, which couldn't reflect the influence of duration of cooperation on its winning probability well.
$Signal\_H$	Well-known manufacturer brand *Manu*_1	If the product sold by the seller is a well-known brand, *Manu*_1=1, or *Manu*_1=0
*Tao*_1	Binary variables	If the seller is Taobao, *Tao*_1=1, or *Tao*_1=0
*Tmall*_1	Binary variables	If the seller is Tmall Mall, *Tmall*_1=1, or *Tmall*_1=0
*Jing*_1	Binary variables	If the seller is JD.com Mall, *Jing*_1=1, or *Jing*_1=0
*Su*_1	Binary variables	If the seller is SUNING, *Su*_1=1, or *Su*_1=0

Source: obtained by the author's collating.

The empirical part mainly tests the propositions 3 and 4 of the theoretical research. The two propositions are as follows. The product quality signal set up by the search engine has no significant impact on sellers to obtain the sponsored position. And the seller product quality signal only has a significant impact on sellers to obtain the first sponsored position. The key point of our work is to explore the effectiveness of the product quality signal, so we have the follow econometric model.

$$S_1 = \alpha_0 + \alpha_1 Signal\_B + \alpha_2 Signal\_H + XCon + \varepsilon \quad (1)$$

In the econometric model (1), the dependent variable *S*_1, which is a binary variable, indicates whether the seller wins the auction of the first sponsored position of a set of keywords. The "winning rules" are shown in Table 2. The explanatory variable *Signal_B* represents the product quality signal designed by the search engine for sellers, including the seller reputation certification level *Id*_1 and the length of duration *Tim*_1 of cooperation between the sellers and the search engine. The explanatory variable *Signal_H* represents the product quality signal brought by sellers, and its indicator is the well-known manufacturer brand *Manu*_1. The control variable *Con* contains four binary variables, including *Tao*_1, *Tmall*_1, *Jing*_1, and *Su*_1. ε is a random error term. The indicators of all variables and their meanings are detailed in Table 2.

5.2Data sources and the variable descriptive statistics

We classify the keywords of products and services by an e-commerce enterprise. Then we enter keywords to Baidu Search in an experimental way, view the sponsored search results (advertisements) at the top of the search results page, and collect all the data by hand. Keywords are divided into 17 categories, 103 subcategories, a total of 845 nouns, including 784 keywords in product category and 61 keywords in service category. We give up the service keyword data, because the service keyword data is abnormal without analytical value. What's more, the sample data of product keywords is processed to enhance the representativeness and typicality of the data. First of all, we remove the observation of the sellers without real name verification. If the seller's advertising information is without the "V" certification signal, it is difficult for consumers to identify their reputation status. Secondly, we eliminate the observed values that there is only one sponsored search result at the top of keyword retrieval. Because the search engine might deliberately shorten the list of sponsored search results. The descriptive statistical results of the first sponsored position variable are shown in Table 3. And the results of descriptive statistics of variables in other sponsored positions are shown in schedule 1-2.

Table 3 The descriptive statistical results of the first sponsored position variable

Variable	Mean	Median	Std. dev.	Minimum	Maximum	Obs.
*S*_1	0.532	1	0.499	0	1	784
*Id*_1	0.643	1	0.479	1	3	784
*Tim*_1	74.74	79	44.57	1	175	784
*Manu*_1	0.297	0	0.457	0	1	784
*Tao*_1	0.0980	0	0.298	0	1	784
*Tmall*_1	0.148	0	0.355	0	1	784
*Jing*_1	0.151	0	0.358	0	1	784
*Su*_1	0.0690	0	0.253	0	1	784

Source：analyzed by Stata.

In Table 3, the winning rate of keyword auctions for the first sponsored position is 53.2%, that is, the average value of *S*_1 is 0.532.As for the index of the product quality signal *Signal_B*, designed by the search engine, the average value of the real name authentication grade *Id*_1 is 0.643, indicating that 64.3% of the sellers occupying the first sponsored position have real name certification grade V_3. And the average length of duration of cooperation *Tim*_1 is 74.74 months, about 6 years and 3 months. The average value of well-known manufacturer brand *Manu*_1, one of the indexes of sellers' own product quality signal *Signal_H*, is 0.297, indicating that 29.7 % of the products sold are well-known manufacturer brands. The mean values of binary variables *Tao*_1, *Tmall*_1, *Jing*_1 and *Su*_1 are 0.098, 0.148, 0.151 and 0.069 respectively, reflecting that when they participate in the auction of the first sponsored position of keywords, the market shares of Taobao, Tmall Mall, JD.com Mall and SUNING are 8.8%, 14.8%, 15.1% and 6.9% respectively, totaling 46.6%. These data show that oligarch sellers have the ability to change the auction equilibrium in the keyword auction market, which means they have monopoly market power. The following empirical results will further confirm this view.

5.3 Discussion of results

It is not difficult to find the fact whether sellers can win the first sponsored position auction is a probability event from the sample data. Therefore, we implement the probability regression model for regression analysis. The empirical results are shown in Table 4 and Table 5.The regression results (1) to (3) of Table 4 are the Probit regression results of the econometric model (1) (taking the certification level as the index of the explanatory variable *Signal_B*). The regression results (4) and (5) are the results of Probit regression after adding the interaction term between the explanatory variable *Signal_B* and the control variable. The regression results (6) and (7) of Table 5 are the Probit regression results of the econometric model (1) (taking the length of cooperation as the index of the explanatory variable *Signal_B*).The regression results (8) and (9) are the results of Probit regression by adding the interactive term between the explanatory variable *Signal_B* and the control variable.

It’s not difficult to find that the product quality signal designed by the search engine for sellers has no significant promotion for sellers to obtain the first sponsored position of the keyword. Specifically, in the regression results (2) and (3), the regression coefficient of the index *Id_1* of the explanatory variable *Signal_B* is not significant. In the regression results (6) and (7), the regression coefficient of the index *Tim_1* of the explanatory variable *Signal_B* is not statistically significant either. Furthermore, we analyze the channel effect of the explanatory

variable *Signal_B*, that is, the regression results (4), (5), (8) and (9).Accordingly, in the regression results (4), (5), (8) and (9), the symbols and statistical significance of the regression coefficients of the interactive terms are consistent with the theoretical research results, which shows that the product quality signal built by the search engine fails to play the role of information transmission. In particular, the regression coefficient of the interactive term *Id_Jing* in the regression result (5) is negative and statistically significant, which shows that increasing the certification level will reduce the probability for JD.com Mall to obtain the first sponsored position[9]. To sum up, this result is consistent with the equilibrium result of the theoretical model (proposition 3).

In contrast, the product quality signal brought by the seller can significantly promote sellers to obtain the first sponsored position. Specifically, in the regression results (3) to (5) and the regression results (7) to (9), the regression coefficient of *Manu_1*, the index of the seller's own product quality signal *Signal_H*, is positive and statistically significant, indicating that when the brands sold by sellers is well-known brands, the probability of obtaining the first sponsored position will increase significantly. And the value of the regression coefficient also reflects that the probability for sellers of well-known brands to get the first sponsored position will be higher than that of non-well-known brands from 74.7% to 88.0%.However, the improvement effect of sellers' own product quality signals on the information matching efficiency under the sponsored search auction mechanism is limited to the first sponsored position. There is no improvement effect on other sponsored positions. See schedule 4-11 for details. In summary, the empirical results support the theoretical proposition 4.

Table 4 Probit regression results of the econometric model (1) (based on the certification level)

	(1)	(2)	(3)	(4)	(5)
	S_1	*S_1*	*S_1*	*S_1*	*S_1*
Tao_1	1.262***	1.201***	1.572***	1.566***	1.566***
	(0.296)	(0.332)	(0.359)	(0.354)	(0.360)
Tmall_1	1.178***	1.138***	1.160***	1.196***	1.157***
	(0.243)	(0.232)	(0.242)	(0.442)	(0.241)
Jing_1	1.371***	1.311***	1.611***	1.606***	5.087***
	(0.264)	(0.297)	(0.322)	(0.324)	(0.276)
Su_1	0.731**	0.669**	0.949***	0.944***	0.944***
	(0.313)	(0.330)	(0.346)	(0.349)	(0.346)
Id_1		0.103	-0.122	-0.115	-0.115
		(0.162)	(0.171)	(0.189)	(0.172)
Manu_1			0.631***	0.627***	0.627***
			(0.163)	(0.162)	(0.163)
Id_Tmall				-0.0473	
				(0.428)	
Id_Jing					-3.488***
					(0.335)
_cons	-0.448***	-0.490***	-0.635***	-0.637***	-0.637***
	(0.142)	(0.154)	(0.175)	(0.177)	(0.175)
N	784	784	784	784	784
Observations clustered	Yes	Yes	Yes	Yes	Yes
pseudo R^2	0.154	0.155	0.181	0.181	0.181

Source：analyzed by Stata software.

Note: *p<0.1; **p<0.05; ***p<0.01.

[9] It should be pointed out that the regression result is omitted due to the collinearity between *Tao_1* and the interaction term *Id_Tao* of authentication level *Id_1*. The same is true of the other three interaction items, *Id_Su*, *Tim_Tao*, and *Tim_Su*.

Table 5 Probit regression results of the econometric model (1) (based on the duration of cooperation)

	(6) *S_1*	(7) *S_1*	(8) *S_1*	(9) *S_1*
Tao_1	1.177***	1.473***	1.443***	1.478***
	(0.308)	(0.327)	(0.328)	(0.327)
Tmall_1	1.120***	1.108***	2.635***	1.109***
	(0.238)	(0.241)	(1.023)	(0.241)
Jing_1	1.230***	1.513***	1.473***	-2.059
	(0.285)	(0.311)	(0.309)	(5.113)
Su_1	0.646**	0.857***	0.830**	0.860***
	(0.318)	(0.330)	(0.330)	(0.330)
Tim_1	0.107	0.0105	0.0353	0.00813
	(0.0678)	(0.0674)	(0.0745)	(0.0674)
Manu_1		0.584***	0.558***	0.592***
		(0.159)	(0.160)	(0.160)
Tim_Tmall			-0.366	
			(0.241)	
Tim_Jing				0.728
				(1.048)
_cons	-0.831***	-0.705**	-0.784***	-0.699**
	(0.278)	(0.277)	(0.301)	(0.276)
N	784	784	784	784
Observations clustered	Yes	Yes	Yes	Yes
pseudo R^2	0.158	0.180	0.182	0.180

Source：analyzed by Stata software.

Note: *p<0.1; **p<0.05; ***p<0.01.

However, the regression results of control variables highlight the partial improvement effect of sellers' own product quality signals. Due to the oligopoly of the auction market, the four oligopoly sellers have no incentive to use market signals to transmit product quality information. Specifically, in the regression results (1) to (8), the regression coefficients of binary variables *Tao_1*, *Tmall_1*, *Jing_1* and *Su_1* are all positive and statistically significant, indicating that the probability of four oligarch sellers to occupy the first sponsored positions is higher than that of other types of sellers. In addition, in terms of the value of the regression coefficient, the coefficients of all variables except SUNING are greater than 1, reflecting that the probability of sellers other than four oligarchic sellers (a total of 780) arranged by the search engine at the first sponsored positions is less than 20%.In other words, the four oligopoly sellers form a monopoly on the first sponsored positions by keyword auctions.

5.4 Robustness test

We examine the incentive of oligarch sellers to truly report product quality by adding an interactive term of product quality signals between oligarch sellers and other sellers to the econometric model (1). Furthermore, we explore the partial improvement effect of sellers' own product quality signals under the sponsored search auction mechanism, so as to test the robustness of the empirical results. The specific results are shown in Table 6.

Table 6 Probit regression results with intersecting terms

	(8) *S_1*	(9) *S_1*	(10) *S_1*	(11) *S_1*	(12) *S_1*	(13) *S_1*
Id_1	-0.0801	-0.114	-0.150			
	(0.169)	(0.171)	(0.176)			
Tim_1				0.0296	0.0148	-0.00162
				(0.0689)	(0.0672)	(0.0685)
Manu_1	0.553***	0.608***	0.697***	0.490***	0.559***	0.648***

	(0.186)	(0.173)	(0.180)	(0.184)	(0.169)	(0.176)
*Tao*_1	1.517***	1.558***	1.614***	1.422***	1.460***	1.507***
	(0.354)	(0.362)	(0.366)	(0.322)	(0.329)	(0.331)
*Tmall*_1	0.987***	1.158***	1.168***	0.905***	1.108***	1.111***
	(0.302)	(0.241)	(0.246)	(0.308)	(0.240)	(0.243)
*Jing*_1	1.564***	1.600***	1.741***	1.461***	1.500***	1.636***
	(0.316)	(0.323)	(0.342)	(0.305)	(0.311)	(0.329)
*Su*_1	0.904***	0.884**	0.983***	0.818**	0.785**	0.883***
	(0.342)	(0.379)	(0.351)	(0.327)	(0.363)	(0.334)
Tmall_Manu	0.369			0.451		
	(0.416)			(0.424)		
Su_Manu		0.473			0.522	
		(0.679)			(0.674)	
Jing_Manu			-0.855*			-0.798*
			(0.466)			(0.458)
_cons	-0.623***	-0.630***	-0.650***	-0.737***	-0.711**	-0.686**
	(0.175)	(0.175)	(0.178)	(0.278)	(0.276)	(0.277)
N	784	784	784	784	784	784
Observations clustered	Yes	Yes	Yes	Yes	Yes	Yes
pseudo R^2	0.182	0.182	0.184	0.182	0.181	0.183

Source：analyzed by Stata software.

Note: *p<0.1; **p<0.05; ***p<0.01.

Summing up the regression results in Table 6, the oligarch sellers do not use the product quality signal to report the real product quality to the search engine. In particular, the seller Taobao has never used well-known brands as a product quality signal to report product quality to the search engine. Therefore, there is no regression result between the interaction term of the binary variable *Tao_1* and the variable *Manu_1* of the seller's own product quality signal. As for other sellers, in the regression results (10) and (13), the regression coefficient of the interaction term between the binary variable *Tmall_1* and the seller's own product quality signal *Manu_1* is positive, but it is not statistically significant. In the regression results (12) and (14), the same is true of the regression coefficient of the interaction term between the binary variable *Su_1* and the seller's own product quality signal *Manu_1*.It reflects that Tmall Mall and SUNING, as oligarch sellers, do have no significant incentive to adopt the product quality signals brought by sellers to improve the probability of obtaining the first sponsored positions. But this result cannot be attributed to the reluctance of well-known brand manufacturers to license them, because for any manufacturer, the access to Tmall Mall and SUNING means the access to a large number of consumers. Besides, in the regression results (12) and (15), the regression coefficient of the interaction term between the binary variable *Jing_1* and the seller's own product quality signal *Manu_1* is negative and statistically significant, indicating that if the sales right of well-known brands is explicitly granted to JD.com Mall, the probability of well-known brands obtaining the first sponsored positions will be reduced. In other words, JD.com Mall has no incentive to use the product quality signals brought by sellers to transmit product quality information to the search engine. At the same time, in the regression results (10) to (15), the regression coefficients of the four binary variables *Tao_1*, *Jing_1*, *Tmall_1* and *Su_1* are positive and statistically significant, indicating that the four oligarch sellers still occupy the first sponsored positions steadily, forming a high degree of competition with other sellers. In brief, the information transmission function of

product quality signal is limited to the auction market except the four oligopoly sellers. However, the total share of all sellers in this market getting the first sponsored positions for keyword auctions is less than 20%. Therefore, the seller's own product quality signal has limitation on the information matching efficiency of the sponsored search auction mechanism.

6. Research Conclusions and Policy Recommendations

We construct a tripartite interaction model among the search engine and its users on both sides, including sellers and consumers. By discussing the bidding equilibrium of sellers under information symmetry and information asymmetry, we analyze the influence of adverse selection, which means sellers hide their real product quality and have an impact on consumer welfare. In addition, we investigate the consumer welfare effect of the auction mechanism under information asymmetry, in order to explore the theoretical mechanism of the product quality signal that improves the consumer welfare effect under the sponsored search auction mechanism. And then the industrial practice data is used for the empirical test. The findings of our work are as follows. The sellers with low product quality are likely to select adversely in order to obtain better sponsored positions to mislead consumers to consume, resulting in double losses to consumer welfare. Sellers with high product quality are willing to use product quality signal to obtain better sponsored positions to encourage consumers to consume, improving consumer welfare. In the case of lacking product quality signal, the equilibrium of the keywords auction cannot match the consumer purchase strategy absolutely, seriously damaging the welfare of consumers. After adding the product quality signal, the search engine could improve the matching degree between the equilibrium of the keywords auction and the consumer purchase strategy, partially improving the consumer welfare effect under the sponsored search auction mechanism. Moreover, this limitation not only reflects the phenomenon that only the first sponsored position has the signal transmission effect, but also shows that the effect of seller's own product quality signal is limited to the keywords auction market without the four oligopoly sellers.

Internet-related policy-making departments should require the mainstream search engines to build practical product quality signal for sellers actively and optimize the identification mechanism of the sellers' own product quality signal. For example, among search engines in Chinese search service market, only Baidu Search has built product quality signal such as Baidu credit certification and accumulation mechanism for sellers. Other mainstream search engines such as 360 Search and Bing Search have not built similar reputation evaluation mechanism. But the credit certification of Baidu Search is not free. We find that the sponsored search auction mechanism of Baidu paid reputation authentication does not play a substantive role when Baidu Search arranges sponsored positions. But Baidu Search can identify the sellers' own product quality signal easily. Obviously, search engines need to reduce authentication fees, and even for free, and proactively certify all sellers accessing the platforms to enhance the actual impact of reputation certification. At the same time, search engines should further identify the sellers' own product quality signal by building well-known brand catalogues, and then encourage sellers to improve product quality and enhance consumer welfare.

There are also some limitations and deficiencies in this work. We fail to build an explanatory model that focuses on the service quality. The theoretical model can be constructed, but it is difficult to test the mathematical conclusions empirically. In fact, we also collect some data of service keyword search, but these sample data cannot reflect the relevant service market

conditions, lacking the typicality and the value of empirical analysis. However, based on the theory research, we will try to communicate with the relevant departments of search engines such as Baidu to mine more valuable data in the course of follow-up research.

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Appendix

Proof of proposition 1:

First of all, the seller H_4 has three options for moving to higher sponsored positions: S_3, S_2, S_1. ①When the seller H_4 moves to the position S_3, the profit difference is $\pi_4^3 - \pi_4 = \sigma^2\beta\pi(\gamma_4)(1-2\sigma) + 2\sigma^4\beta\pi(\gamma_4)$, where π_4^3 is the profit of the seller H_4 at the sponsored position S_3. And we define $\pi_i^j (i = 1,2,3,4; j = 1,2,3,4; i \neq j)$ is the profit of seller H_i at the sponsored position S_j, applying to the following. The seller H_4 has incentives to move to the sponsored position S_3, due to $0 < \sigma < 1/2$, $\sigma\beta\pi(\gamma_4)(1-2\sigma) > 0$ and $\pi_4^3 - \pi_4 > 2\sigma^4\beta\pi(\gamma_4) > 0$. ②When the seller H_4 moves to the sponsored position S_2, its profit difference is $\pi_4^2 - \pi_4 = \sigma\beta\pi(\gamma_4) - \sigma^2\beta\pi(\gamma_3)$. If $\pi(\gamma_4) < \sigma\pi(\gamma_3)$, then $\pi_4^2 - \pi_4 < 0$, which means the seller H_4 has no incentive to move to the sponsored positionS_2. If $\pi(\gamma_4) > \sigma\pi(\gamma_3)$, then $\pi_4^2 - \pi_4 > 0$, which means the seller H_4 has incentives to move to the sponsored position S_2. ③When the seller H_4 moves to the sponsored position S_1, its profit difference is $\pi_4^1 - \pi_4 = \beta[\pi(\gamma_4) - \sigma\pi(\gamma_2) + \sigma^2\pi(\gamma_3) - 2\sigma^3\pi(\gamma_4) + 2\sigma^4\pi(\gamma_k)]$. If $\pi(\gamma_4) < \sigma\pi(\gamma_3)$, then $\sigma^2\beta\pi(\gamma_3) - 2\sigma^4\beta\pi(\gamma_4) > \sigma^2\beta\pi(\gamma_3) - 2\sigma^4\beta\pi(\gamma_3) = \sigma^2\beta\pi(\gamma_3)(1-2\sigma^2)$ and $0 < \sigma < 1/2$, so $\sigma^2\beta\pi(\gamma_3) - 2\sigma^4\beta\pi(\gamma_4) > \sigma^2\beta\pi(\gamma_3)/2 > 0$. The condition for the seller H_4 having incentives to move to the sponsored position S_1 is $\pi_4^1 - \pi_4 > 0$, i.e. $\pi(\gamma_2) < \sigma\pi(\gamma_3) - 2\sigma^2\pi(\gamma_4) + 2\sigma^3\pi(\gamma_k) + (\pi(\gamma_4)/\sigma)$. At the same time, the condition for the seller H_4 having no incentive to move to the sponsored position S_1 is $\pi_4^1 - \pi_4 < 0$, that is $\pi(\gamma_2) > \sigma\pi(\gamma_3) - 2\sigma^2\pi(\gamma_4) + 2\sigma^3\pi(\gamma_k) + (\pi(\gamma_4)/\sigma)$. If $\pi(\gamma_4) > \sigma\pi(\gamma_3)$, then $\pi_4^1 - \pi_4 > 0$, that is $\pi(\gamma_2) < (1 + \sigma - 2\sigma^2)\pi(\gamma_3) + 2\sigma^3\pi(\gamma_k)$, the seller H_4 has incentives to move to sponsored position S_1. If $\pi_4^1 - \pi_4 < 0$, that is $\pi(\gamma_2) > (1 + \sigma - 2\sigma^2)\pi(\gamma_3) + 2\sigma^3\pi(\gamma_k)$, the seller H_4 has no incentive to move to the sponsored position S_1. The constraints that the seller H_4 has incentives to move to

the sponsored position S_1 are more stringent than those of the sponsored position S_2. The constraints of moving to the sponsored position S_2 are more stringent than those of moving to the sponsored position S_3.As a result, the seller H_4 has incentives to move to a higher sponsored position, and the incentives weaken with the sponsored position rising.

Secondly, the seller H_3 has two options for moving to higher sponsored positions: S_2 and S_1.There is only one option to move to a lower sponsored position, i.e. S_4.①When the seller H_3 moves to the sponsored position S_2, its profit difference is $\pi_3^2 - \pi_3 = \sigma\beta\pi(\gamma_3)(1-2\sigma) + 2b_3$. Because $0 < \sigma < 1/2$, $\sigma\beta\pi(\gamma_3)(1-2\sigma) > 0$ and $\pi_3^2 - \pi_3 > 2b_3 > 0$, the seller H_3 has incentives to move to the sponsored position S_2. ②When the seller H_3 moves to the sponsored position S_1, its profit difference is $\pi_3^1 - \pi_3 = \beta\pi(\gamma_3) - \sigma\beta\pi(\gamma_2)$. If $\pi(\gamma_3) > \sigma\pi(\gamma_2)$, then $\pi_3^1 - \pi_3 > 0$, which means the seller H_3 has incentives to move to the sponsored position S_1. If $\pi(\gamma_3) < \sigma\pi(\gamma_2)$, then $\pi_3^1 - \pi_3 < 0$, which means the seller H_3 has no incentive to move to the sponsored position S_1.③ When the seller H_3 moves to the sponsored position S_4, its profit difference is $\pi_3^4 - \pi_3 = \sigma^3\beta\pi(\gamma_3) - \sigma^2\beta\pi(\gamma_3) + \sigma^2\beta\pi(\gamma_4) - 2b_4$. As $\pi(\gamma_4) < \pi(\gamma_3)$, $0 < \sigma < 1/2$ and $\pi_3^4 - \pi_3 < 0$, the seller H_3 has no incentive to move to the sponsored position S_4. As a result, the seller H_3 has incentives to move to a higher sponsored position, and the incentives weaken as the sponsored position rises. But the seller H_3 has no incentive to move to a lower sponsored position.

Then, the seller H_2 has only one option for moving to a higher sponsored position, i.e. S_1. And the seller H_2 has two options for moving to lower sponsored positions: S_3 and S_4. ① When the seller H_2 moves to the sponsored position S_1, its profit difference is $\pi_2^1 - \pi_2 = \sigma\beta\pi(\gamma_2)(1-2\sigma) + 2b_2$. Because $0 < \sigma < 1/2$, $\sigma\beta\pi(\gamma_2)(1-2\sigma) > 0$ and $\pi_2^1 - \pi_2 > 0$, the seller H_2 has incentives to move to the sponsored position S_1.②When the seller H_2 moves to the sponsored position S_3, its profit difference is $\pi_2^3 - \pi_2 = \sigma^2\beta\pi(\gamma_2) - \sigma\beta\pi(\gamma_2) + \sigma^2\beta\pi(\gamma_3) - 2b_3$. Because $\pi(\gamma_3) < \pi(\gamma_2)$, $0 < \sigma < 1/2$ and $\pi_2^3 - \pi_2 < 0$, the seller H_2 has no incentive to move to the sponsored position S_3. ③When the seller H_2 moves to the sponsored position S_4, its profit difference is $\pi_2^4 - \pi_2 = \sigma^3\beta\pi(\gamma_2) - \sigma\beta\pi(\gamma_2) + \sigma^2\beta\pi(\gamma_3) - \sigma^3\beta\pi(\gamma_4)$. Because $\pi(\gamma_3) < \pi(\gamma_2)$, $0 < \sigma < 1/2$ and $\pi_2^4 - \pi_2 < 0$, the seller H_2 has no incentive to move to the sponsored position S_4. As a result, the seller H_2 has an incentive to move to a higher sponsored position, but not to a lower sponsored position.

The seller H_4, H_3 and H_2 all have incentives to change the current sponsored positions, while the seller H_1 has no incentive to move lower positions. The seller H_1 has three options for moving to lower sponsored positions: S_2, S_3 and S_4.①When the seller H_1 moves to the sponsored position S_2, its profit difference is $\pi_1^2 - \pi_1 = \sigma\beta\big(\pi(\gamma_1) + \pi(\gamma_2)\big) - \beta\pi(\gamma_1) - 2b_2$. Because $\pi(\gamma_1) > \pi(\gamma_2)$, $0 < \sigma < 1/2$ and $\pi_1^2 - \pi_1 < -2b_2 < 0$, the seller H_1 has no incentive to move to the sponsored position S_2.②When the seller H_1 moves to the sponsored position S_3, its profit difference is $\pi_1^3 - \pi_1 = \sigma^2\beta\pi(\gamma_1) + \sigma\beta\pi(\gamma_2) - \beta\pi(\gamma_1) - \sigma^2\beta\pi(\gamma_3)$. Because $\pi(\gamma_1) > \pi(\gamma_2)$, $0 < \sigma < 1/2$ and $\pi_1^3 - \pi_1 < 0$, the seller H_1 has no incentive to move to the sponsored position S_3.③ When the seller H_1 moves to the sponsored position S_4, its profit difference is $\pi_1^4 - \pi_1 = \sigma^3\beta\pi(\gamma_1) + \sigma\beta\pi(\gamma_2) - \beta\pi(\gamma_1) + \delta$, where $\delta = \big(\sigma^3\beta\pi(\gamma_4) - \sigma^2\beta\pi(\gamma_3) - 2\sigma^4\beta\pi(\gamma_k)\big)$, $\pi(\gamma_4) < \pi(\gamma_3)$ and $\delta < 0$. Because $\pi(\gamma_1) > \pi(\gamma_2)$, $0 < \sigma < 1/2$ and $\pi_1^4 - \pi_1 < 0$, the seller H_1 has no incentive to move to the sponsored position S_4.

The proof of the bidding equilibrium ranking in case ②:

The sponsored positions S_1 to S_4 are randomly assigned. When the service provider H_k

chooses to falsely report the quality of service and is assigned to the sponsored positions S_1, S_2, S_3 or S_4, the profits are as follows.

$$(\pi_k^1)_1 = \beta[\pi(\gamma_h) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_1)] \quad (1)$$

$$(\pi_k^2)_1 = \beta[\sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_1)] \quad (2)$$

$$(\pi_k^3)_1 = \beta[\sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_1)] \quad (3)$$

$$(\pi_k^4)_1 = \beta[\sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_1)] \quad (4)$$

In equations (1) to (4), $\pi(\gamma_h) > \sigma\pi(\gamma_1)$, $(\pi_k^1)_1 > 0$, $(\pi_k^2)_1 > 0$, $(\pi_k^3)_1 > 0$, $(\pi_k^4)_1 > 0$, which show that service provider H_k can always make a positive profit without worrying about losses. Accordingly, when the service providers H_2 to H_4 choose to falsely report the quality of service and are randomly assigned to the sponsored positions S_1, S_2, S_3 and S_4, their profits are the same as that of the service provider H_k. Therefore, if the service providers H_2 to H_4 choose to falsely report the quality of service, they will always obtain the positive profit. Apparently, the sellers H_2 to H_4 and H_k all have strong incentives for false reporting the service quality.

When the seller H_i chooses to truthfully report the quality of service and is assigned to the sponsored positions S_1, S_2, S_3 or S_4, the profits are as follows.

$$(\pi_i^1)_2 = \beta[\pi(\gamma_i) - \sigma\pi(\gamma_h) + \sigma^2\pi(\gamma_h) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_1)] \quad (5)$$

$$(\pi_i^2)_2 = \beta[\sigma\pi(\gamma_i) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_1)] \quad (6)$$

$$(\pi_i^3)_2 = \beta[\sigma^2\pi(\gamma_i) - \sigma^3\pi(\gamma_h) + \sigma^4\pi(\gamma_1)] \quad (7)$$

$$(\pi_i^4)_2 = \beta[\sigma^3\pi(\gamma_i) - \sigma^4\pi(\gamma_1)] \quad (8)$$

In equations (5) to (8), if $(\pi_i^1)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\pi(\gamma_i) > \sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_h) - \sigma^4\pi(\gamma_1)$. Name the above constraint condition as "constraint condition (1)". If $(\pi_i^2)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\pi(\gamma_i) > \sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_h) + \sigma^3\pi(\gamma_1)$. Name the above constraint condition as "constraint condition (2)". If $(\pi_i^3)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\pi(\gamma_i) > \sigma\pi(\gamma_h) - \sigma^2\pi(\gamma_1)$. Name the above constraint condition as "constraint condition (3)". If $(\pi_i^4)_2 > 0$, the constraint condition of $\pi(\gamma_i)$ is $\pi(\gamma_i) > \sigma\pi(\gamma_1)$. Name the above constraint condition as "constraint condition (4)". Suppose that $\sigma = 0.3, \pi(\gamma_1) = 0.8$ and $\pi(\gamma_h) = 1$, $\pi(\gamma_i) = 0.24$ under the constraint condition (4), $\pi(\gamma_i) > 0.22$ under constraint condition (3), $\pi(\gamma_i) > 0.2316$ under constraint condition (2), $\pi(\gamma_i) > 0.23052$ under constraint condition (1). Through the trial calculation, we know that the constraint condition (4) is the strictest. Increasing the difference between $\pi(\gamma_1)$ and $\pi(\gamma_h)$, we get $\sigma = 0.3$, $\pi(\gamma_1) = 0.8$, $\pi(\gamma_h) = 1.6$. And $\pi(\gamma_i) > 0.24$ under constraint condition (4), $\pi(\gamma_i) > 0.408$ under constraint condition (3), $\pi(\gamma_i) > 0.3576$ under constraint condition (2), $\pi(\gamma_i) > 0.37272$ under constraint condition (1). So, the constraint (3) is the strictest. Therefore, under the strict constraint, the service provider H_i has no incentive to truthfully report the quality of service.

The proof of proposition 2:

In case ①, the combined profit of the sellers H_2 to H_4 and H_k is π_j^1: $\pi_j^1 = \beta[\pi(\gamma_k^1) - \sigma\pi(\gamma_1) + 2\sigma^2\pi(\gamma_2) - \sigma^3\pi(\gamma_3) + \sigma^4\pi(\gamma_4)]$. In case ②, the combined profit of the sellers H_2 to

H_4 and H_k is π_j^2: $\pi_j^2 = \beta[\pi(\gamma_h) - \sigma^4\pi(\gamma_1)]$. The profit difference between them is as follow.

$$\Delta\pi_j^1 = \pi_j^1 - \pi_j^2 = -\beta\left[\left(\pi(\gamma_h) - \pi(\gamma_k^1)\right) + \sigma\pi(\gamma_1) - 2\sigma^2\pi(\gamma_2) + \sigma^3\pi(\gamma_3) - \sigma^4\left(\pi(\gamma_1) + 2\pi(\gamma_4)\right)\right] \quad (9)$$

In equation (9), $\pi(\gamma_4) < \pi(\gamma_3) < \pi(\gamma_2) < \pi(\gamma_1) < \pi(\gamma_k^1) < \pi(\gamma_h)$ and $0 < \sigma < 1/2$. Through the simulation, $\Delta\pi_j^1 < 0$ when the difference of the unit profit of the seller is small, that is, the market competition is fierce. Thus, the best strategy for the sellers H_2, H_3 is to reverse the selection with the seller H_k.

In case ②, the combined profit of seller $H_i(i = 1,2,3,4,k)$ is π_m^2: $\pi_m^2 = \beta[\pi(\gamma_h) + \sigma^2\pi(\gamma_h) + \sigma^4\pi(\gamma_4)]$. In case ③, the combined profit of seller H_i is π_m^3: $\pi_m^3 = \beta[\pi(\gamma_h) + \sigma^2\pi(\gamma_h)]$.

$$\Delta\pi_m^2 = \pi_m^2 - \pi_m^3 = \beta\sigma^4\pi(\gamma_4) \quad (10)$$

In equation (10), $\pi(\gamma_4) > 0$ and $\Delta\pi_m^2 > 0$, so the sellers H_2 to H_4 and H_k select in reverse together, excluding the seller H_1.

To sum up, under information asymmetry and without product quality signal, the sellers H_2 to H_4 and H_k select in reverse together at the state of equilibrium, and the seller H_1 reports product quality at the same time. Therefore, the equilibrium of bidding rank of case ② is Nash equilibrium under information asymmetry and without product quality signal. Proof is over.