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Abstract: With the diversification of paid search advertising channels, e-commerce enterprises are paying more and more attention on how to evaluate the effectiveness of different paid search advertising channels correctly and accurately to choose the optimal advertising channel or channels. We develop a multivariate time series model to investigate the spillover effect of paid search advertising channels based on the ad click-through rate and conversion rate, and calibrate the model using an e-commerce site's web log data. We determine the long-term equilibrium relationship between each channel's advertisement clicks through the co-integration test and evaluate the effect of short-term fluctuations in the interaction between each channel advertisement clicks through the vector error correction model. Based on the empirical results, this paper puts forward suggestions on the advertising strategy of this e-commerce website.

Keywords: spillover effect, paid search advertising channel, co-integration, vector error correction model, time series model

1. INTRODUCTION

With the development of search engines, paid search advertising, which is an important economic basis for search engines, is getting more and more attention. By the end of the first half of 2017, paid search advertising accounted for 26.35% of all online advertisements in our country, ranking the second largest form of internet advertising. Paid search ads can offer more opportunities for businesses to promote their own websites , which make paid search ads have become one of the main venues where companies competing for customers[1]. Therefore, how to improve advertising effectiveness and stimulate more consumers to generate clicks is becoming the focus of every e-commerce enterprise.

Paid search advertising is one of the most successful business patterns of Internet advertising. Generally, the enterprises purchase the specific keywords related to its business, when consumer use the keyword search for products or services, search engine will display ads involved with the keywords the company has bought in the sponsored link module of search results page [2]. Different companies bidding on keywords, mainly based on bidding keyword technology, rank these advertising links. In order to provide useful advice to businesses on the choice of keywords and improve the enterprises economic benefits by increasing the audience of advertisements, most of the current researches on how to improve the effectiveness of paid search ads focus on how to optimize the keywords of paid search ads. In addition, there are also some studies focusing on the impact of the design of advertising content on the purchase conversion effect. Nevertheless, there are few studies on paid search advertising channels. Moreover, the research for paid search advertising channels are more concentrated in evaluating the effectiveness of advertising channel by measuring the immediate effects of advertising in a specific search channel.

With the continuous expansion of the search engine market, businesses are increasingly becoming more selective in choosing channels to run paid search advertising. For example, enterprises can bid on keyword search ads on multiple search engines (e.g. Baidu, 360 etc.) by evaluating the immediate effect of specific advertising channels (the impact of Paid Search Advertising on consumer's current ad click or conversion),

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making the enterprises have possibility of choosing wrong advertising channels. Considering the immediate effect reflects purchase conversion resulting from the recently click on an ad, yet consumers will not generate click on ads or purchase conversion through just one search (the search channel does not have an immediate effect). Under the environment of multiple search channels, consumers are usually not limited to one single search channel, and the ad click behavior of consumers in a particular search channel may have an impact on their subsequent search or advertisement click behavior. The interaction between paid search ads channels is the spillover effect of paid search advertising channels. This spillover effect is particularly important for enterprises to choose the right channel or channel combination to improve their advertising effectiveness. Therefore, we develop a multivariate time series model to investigate the spillover effect of paid search advertising channels according to both ad click-through rate and conversion rate based on the actual web log data from an e-commerce website. Firstly, we determine the long-term equilibrium relationship between each channel's advertisement clicks through the co-integration test. Secondly, we evaluate the effect of short-term fluctuations in the interaction between each channel advertisement clicks through the vector error correction model. Finally, we use the impulse response functions to reveal the spillover effect between paid search advertising channels intuitively. Based on the empirical results, this paper puts forward suggestions on the advertising strategy of this e-commerce website.

The remainder of this article is organized as follows. In Chapter 2, we mainly review the relevant literature. In Chapter 3, we mainly present the data, including the data extraction process and the main features of the data. In Chapter 4, we will present our modeling methodology and analyze the modeling results. In Chapter 5, we will do summary, discusses the shortcomings of our study, and promote the direction of future research.

2. LITERATURE REVIEW

The literature review mainly introduces two aspects, which provides a theoretical basis for our study. On the one hand, we will introduce the researches on paid search advertising; on the other hand, we will introduce the spillover effect and the application of spillover effect research.

2.1 Paid search advertising

Paid search advertising is a service offered by Internet search engines, based on keyword bidding technology. When a user searches for those keywords, the corresponding ads will be displayed in the sponsored section of the search results page. If companies do not select the right keywords, they may show the product to the improper consumers, eventually leading to poor ad performance [3]. Therefore leveraging bidding keywords to achieve the match between paid search advertising and search terms of consumers is very important for companies. Numerous research efforts has been devoted to optimizing keyword suggestions to improve the effectiveness of paid search advertising [4, 5]. Massoudi et al. selected the related terms co-occurring with the original query to augment the query keywords through the conditional probabilities [6]. Sarmento et al. through analyzed the correlation between query content and click-link behavior, got the keywords that are directly related to the business value of the enterprise [7]. In addition, there are some studies discussing how to improve the ads' click-through rate and ads' conversion rate based on the advertising content design [8]. Such as Jansen et al. proved content description and ad title are the most important part of evaluating paid search ads [9]. Rutz,Trusov et al. believed that the brightness and density of paid search advertising content have a significant impact on effectiveness of advertising[5].

We can find that the current researches on paid search advertising mainly focus on the keyword suggestion method and advertisement content design, while the researches on the paid search-advertising channel (search engine) are scarce. At present, the search channels for advertising on the Chinese market mainly include Baidu

search engine, Sougou search engine, 360-search engine, Ali cloud search and so on. With the optimization of keyword suggestion method and bidding mechanism, the cost of paid search advertising has increased. Meantime, the emergence of the diversified channels of paid search advertising have brought some challenges to enterprises on how to choose suitable advertising channels,making companies pay more attention to how to choose advertising channels or channel combinations to maximize the advertising effectiveness. Therefore, our study attempts to analyze the interaction between different paid search advertising channels and provide evidence for enterprises to choose the appropriate paid search advertising channels or channel combinations. The sample data for our study came from an insurance e-commerce website. The mainly paid search advertising channels of this enterprise are Baidu, Sougou and 360 search. We will primarily model and analyze the benefits of these three paid search advertising channels.

2.2 Spillover effect

The spillover means overfill and flow-out. In economics, spillover specifically represents activity externality. The concept of spillover is the effect of one agent on the welfare of other agents, originally proposed by Marshall in his book Principles of Economics. Stiglitz argued that the additional costs and benefits that are not included in the market transactions are spillover effects. This laid the theoretical foundation for the study of spillover effects, after which scholars began to pay attention to the spillover effect on economic growth and productivity. The researches on spillover effect mainly focused on the risk assessment or price changes in the financial field. For example, Farooq et al. analyzed the conduction mechanism of the volatility period of the oil price in the U.S. and Gulf stock markets based on the multivariate GARCH model [10]. Diebold and Yiimaz studied the two-way financial market spillover through the VAR framework [11].

With the development of online advertising, scholars have introduced spillover effects into the field of online advertising research. Naik and Peters proposed a hierarchical model to uncover the spillover effect between offline and online ads [12]. Based on the performance of specific keywords, Ghose and Yang explored the spillover effect between natural search and paid search [13]. Rutz and Bucklin proposed a dynamic linear model to study the potential spillover effect of paid search from generic keywords to brand keywords [14]. Florian Nottorf et al. further extended the method of Rutz et al. and use DLM model to study the spillover effects in cross-industry paid search advertising [15]. Pavel Kireyev et al. modeling the spillover effect between display and paid search ads, based on multivariable time series model [16].

We can find that the existing researches on the spillover effect of search ads mainly focused on specific search engines, lacking of in-depth exploration on multiple search engines (search-advertising channels). However, in fact, consumers will not generate click on ads or purchase conversion through just one search. Assuming that a consumer searches for a particular product keyword at a time, he may not react to the ads (ad click or ad purchase conversion) of this channel immediately. He will make a purchase after a series of searches at subsequent times. In the subsequent search process, the search channels used by consumers may change due to the search environment or personal preferences. Based on the click-through behavior of consumers on multiple paid search advertising channels, this paper explores the interactive effect of the effectiveness of paid search advertising channels, namely, the spillover effect. Considering the specific business process and data characteristics of our research object, we finally chooses the multivariable time series modeling method to analyze the spillover effect between paid search advertising channels. The specific content will be introduced in later chapters.

3.   DATA DESCRIPTION

We use data from an insurance e-commerce website. In the year 2016, the website provided us the annual

server log data on the website's online marketing. In the log data, the server records each click of the user to form the user's click stream data. We need to clean and convert the raw data to get the relevant data variables that describe the paid search ads and their advertising channels. Specific data extraction process is as follows.

Firstly, we remove the invalid data such as reptile data and get the data about user IP, access time, website agent, source webpage, and cookie during the process of obtaining the original data. Secondly, we do the user identification based on cookies. When the user disables the cookie, we use IP address in conjunction with the user agent to identify the user. Thirdly, we need to do the session segmentation on the user's access because those users may complete multiple business when they visit a page. In our study, we do not adopt the traditional method of session segmentation by setting the time threshold value, we segment session based on the users' purchase behavior. We determine whether the user has made a purchase, and treat each purchase as a session cut point. The click behavior before the purchase as a single session process. Then we extract variables from the process of session, and identify the user's click behavior based on the keyword contained in a specific URL. Finally, we obtain the data of paid search advertising clicks and purchases conversions completed by consumers in different search channels.

The mainly paid search advertising channels of this insurance website are Baidu search, 360 search and Sougou search engines. We aggregate our data of clicks and purchase conversions to the week level (52 weeks a year) to avoid over-parameterization. Table 1 presents the specific meaning of the variables used in this paper.

Table 1. Variable description

Variable	Description (weekly)
Baidu_C	Baidu paid search ad clicks
Search360_C	360 search paid search ad clicks
Sougou_C	Sougou paid search ad clicks
Baidu_P	Purchase conversions through Baidu paid search ad
Search360_P	Purchase conversions through 360 search paid search ad
Sougou_P	Purchase conversions through Sougou paid search ad

Table 2 provides summary statistics of our data.

Table2. Summary statistics (per week)

Variable	Baidu_C	Search360_C	Sougou_C	Baidu_P	Search360_P	Sougou_P
Mean	6839.08	7412.00	2895.08	192.04	147.15	79.50
Median	6519.00	6854.00	2530.50	179.00	149.00	82.00
Maximum	11453.00	19660.00	7838.00	320.00	264.00	134.00
Minimum	1925.00	45.00	752.00	51.00	5.00	15.00
Std Dev	2193.97	3590.70	1326.44	69.81	65.03	28.69

4. MODELING AND ANALYSIS

Our study uses the time series modeling approach to measure the spillover effect between paid search advertising channels. The specific research process is as follows.

4.1 Modeling and parameter estimates

Persistence modeling of multivariate time series methods involves several steps.

The time series model requires that each variable be a stationary sequence to avoid the spurious regression. Therefore, we conduct Augmented-Dickey-Fuller (ADF) unit root test to determine if the variables are evolving or stationary. Table 3 summarizes the resulting statistics of the unit root tests. The result of the unit root test shows that all variables are evolving. And the result of the unit root test of variables after One Order Difference

shows that Baidu_C，Search360_C，Sougou_C and Sougou_P are integrated of order 1.

Table3. Summary of results of unit root test

Test\variable	Baidu_C	Search360_C	Sougou_C	Baidu_P	Search360_P	Sougou_P
Original sequence	**-3.6568**	**-2.1648**	**-1.865**	**-2.2019**	**-3.0157**	**-2.0163**
Differenced sequence	-5.279	-5.4368	-5.9187	**-3.6893**	**-3.7344**	-4.972

Note: Bold numbers indicate significant evidence of non-stationarity.

The co-integration relationship test is then used to determine whether the linear combination of variables has a co-integration relationship, which indicates the long-term equilibrium relationship between the two variable sequences. Co-integration test the basic steps are as follows:

(1) Confirm the single integer order of variables. Through unit root test, we know that Baidu_C, Search360_C, Sougou_C and Sougou_P are first-order integrated series. Because the co-integration test requires that the variables are integrated of same order, so the follow study excludes variables Baidu_P and Search360_P, and uses the variables Baidu_C, Search360_C, Sougou_C and Sougou_P for analysis.

(2) Estimate the long-run equilibrium relationship. We use Eq. (1) to estimate long-run equilibrium relationship.

$$Y_t = \alpha + \beta X_t + \mu_t \quad (1)$$

If the variables are co-integrated, the estimates of the co-integration coefficients α and β are obtained by regression. In order to determine if the covariates exist between the variables, we need to do unit root test for the residuals. If the residuals are stationary, then we can tell that the co-integration relationship is real. Eq. (2) represents the residual sequence model.

$$\hat{\mu}_t = Y_t - \left(\hat{\alpha} + \hat{\beta} X_t\right) \quad (2)$$

(3) Residual sequence stationary test. The residual ADF test show that the sequence is stationary, indicating that this long-term equilibrium relationship indeed exists among the variables. Eq. (3) represents the estimation of the long-run equilibrium relationship between variables.

$$
\begin{bmatrix}
Search360\_C \\
Search360\_C \\
Search360\_C \\
Baidu\_C \\
Baidu\_C \\
Baidu\_C \\
Sougou\_C \\
Sougou\_C \\
Sougou\_C \\
Sougou\_P \\
Sougou\_P \\
Sougou\_P
\end{bmatrix}
=
\begin{bmatrix}
-3.55 \\
2.11 \\
2.06 \\
7.52 \\
3.86 \\
6.81 \\
-0.13 \\
2.78 \\
5.71 \\
-3.67 \\
1.54 \\
-1.14
\end{bmatrix}
+
\begin{bmatrix}
1.39 Baidu\_C \\
0.83 Sougou\_C \\
1.54 Sougou\_P \\
0.14 Search360\_C \\
0.62 Sougou\_C \\
0.48 Sougou\_P \\
0.91 Search360\_C \\
0.13 Baidu\_C \\
0.51 Sougou\_P \\
0.91 Search360\_C \\
0.32 Baidu\_C \\
0.67 Sougou\_C
\end{bmatrix}
+ \mu_t \quad (3)
$$

Based on the outcomes of the unit root and co-integration tests, we specify a vector error correction model (VEC). The general form of the VEC model with K lags is given by Eq. (4):

$$\Delta Y_t = \gamma_0 D_t + \sum_{k=1}^{K} \gamma_k \Delta Y_{t-k} + \alpha e_{t-1} + \mu_t \quad (4)$$

In Eq.(4), Y_t is a vector of endogenous variables at time t, D_t is a vector of deterministic components (eg, intercept, trend), e_{t-1} is a matrix of co-integration relations, γ_k and α are The parameter matrix to be estimated, Σ is the covariance matrix of the error term μ_t. The coefficients in γ_k account for the effect of past changes in endogenous variables on their current bias. The coefficients in α reflect the speed of adjustment of the endogenous variables to the equilibrium co-ordination relationship. The Bayesian Information Criterion identifies a lag-length of 3 as optimal, and the resulting VEC model is indicated in Eq. (5)

$$
\begin{bmatrix} \Delta BaiduC_{,t} \\ \Delta Search360C_{,t} \\ \Delta SougouC_{,t} \\ \Delta SougouP_{,t} \end{bmatrix} =
$$

$$
\begin{bmatrix} 1127.0 \\ 550.9 \\ -220.3 \\ 18.6 \end{bmatrix} + \begin{bmatrix} -0.5470 & 0.0982 & -0.0993 & -20.51 \\ -0.6419 & -0.0619 & -0.0061 & -12.14 \\ 0.2369 & -0.0280 & -0.5078 & -18.75 \\ -0.0018 & 0.0025 & -0.0004 & -0.6087 \end{bmatrix} \begin{bmatrix} \Delta BaiduC_{,t-1} \\ \Delta Search360C_{,t-1} \\ \Delta SougouC_{,t-1} \\ \Delta SougouP_{,t-1} \end{bmatrix} +
$$

$$
\begin{bmatrix} -0.5327 & 0.2322 & 0.0510 & 10.5216 \\ -0.1033 & 0.0460 & 0.0242 & 1.2969 \\ 0.2624 & 0.0674 & -0.7414 & -11.0359 \\ -0.0014 & 0.0025 & -0.0004 & -0.3045 \end{bmatrix} \begin{bmatrix} BaiduC_{,t-1} \\ Search360C_{,t-1} \\ SougouC_{,t-1} \\ SougouP_{,t-1} \end{bmatrix} + \begin{bmatrix} \mu_{BaiduC,t} \\ \mu_{Search360C,t} \\ \mu_{SougouC,t} \\ \mu_{SougouP,t} \end{bmatrix} \quad (5)
$$

Through the co-integration test and the vector error correction model (Eq.3 and Eq.5), we obtain the interrelationship between paid search ads clicks in three search channels:

(1) Baidu paid search ad clicks. In the short term, changes in previous Baidu paid search ad clicks have a negative impact on the current 360 paid search ad clicks(-0.6419), and a positive impact on Sougou paid search ad clicks(0.2369). In the long run, Baidu paid search ad clicks have positive impact both on 360 paid search ad clicks and Sougou paid search ad clicks. It is worth mentioning that Baidu paid search ad clicks has the greater effect on the 360 paid search ad clicks (1.39).

(2) 360 paid search ad clicks. In the short term, changes in previous 360 paid search ad clicks have a positive impact on the current Baidu paid search ad clicks(0.0982), and a negative impact on Sougou paid search ad clicks(-0.0280). In the long run, 360 paid search ad clicks have positive impact both on Baidu paid search ad clicks (0.14) and Sougou paid search ad clicks (0.91).

(3) Sougou paid search ad clicks. In the short term, changes in previous Sougou paid search ad clicks have negative impact both on Baidu paid search ad clicks (-0.0993) and 360 paid search ad clicks (-0.0061). In the long run, Sougou paid search ad clicks have positive impact both on Baidu paid search ad clicks and 360 paid search ad clicks, and the impact on 360 paid search ad clicks is greater (0.83).

4.2 Impulse response analysis

In order to reveal the spillover effect intuitively, we still use impulse response functions to analyze the impact of paid search ads clicks on different search channels, the results are as follows.
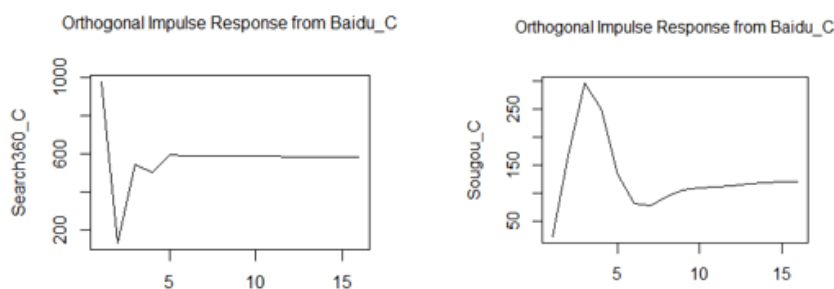

Figure1. Impact of Baidu paid search ad clicks on others

Fig. 1 shows the effect of Baidu paid search ad clicks on other two paid search ad channels are both powerful. In the short term, a shock of Baidu paid search ad clicks generates about 1000 360 paid search ad clicks immediately. After five weeks, 360 paid search ad clicks dip and then stabilize at about 600 clicks in the long run. In contrast, Baidu paid search ad clicks has a weaker effect on Sougou paid search ad clicks, but still positive . Therefore, when enterprises advertise in the 360 search engine or Sougou search engine, they can refer

to the situation of Baidu paid search ad clicks and choose the advertising channel or channel combination that can maximize the paid search advertising benefit.
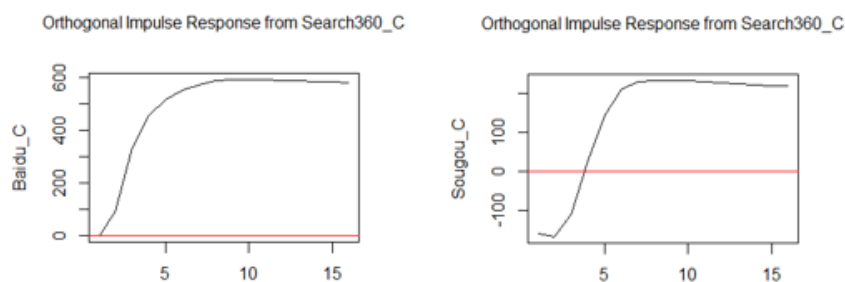

Figure2. Impact of 360 paid search ad clicks on others

Fig.2 shows the impact of 360 paid search ad clicks on other two paid search ad channels. The original shock of 360 paid search ad clicks generates few clicks of Baidu paid search ad clicks and Sougou paid search ad clicks immediately. However, Baidu paid search ad clicks increase then stabilize at about 600 clicks and Sougou paid search ad clicks increase then stabilize at about 150 clicks in the long run.
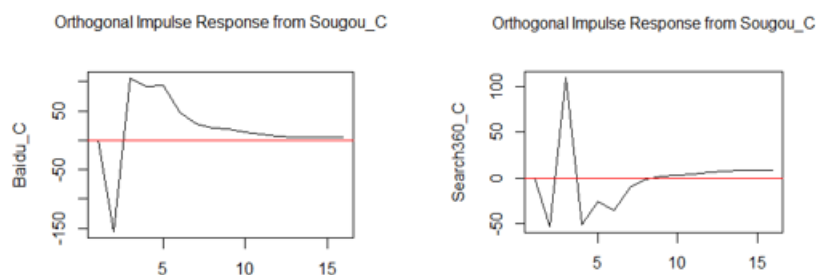

Figure3. Impact of Sougou paid search ad clicks on others

Fig.3 shows the impact of Sougou paid search ad clicks on other two paid search ad channels. In the short term, the effect of Sougou paid search ad clicks on other two paid search ad channels are both significant and fluctuating. Nevertheless, in the long run, Sougou paid search ad clicks has no significant impact on the Baidu paid search ad clicks and 360 paid search ad clicks.

In sum, the impulse response analysis suggests that Baidu paid search ad clicks may drive 360 paid search ad clicks and Sougou paid search ad clicks. With the same, 360 paid search ad clicks may drive Baidu paid search ad clicks and Sougou paid search ad clicks too. The spillover effect can be determined among three search channels in both short term and long run. Therefore, enterprise can dynamically adjust advertising channels based on business changes and advertising historical performance. When the clicks on a channel's paid search ads change, the company can adjust their investment strategies for other channels to choose different channel combinations to achieve higher return on investment.

5.   CONCLUSIONS

Our study analyzed the spillover effect of different paid search advertising channels to make e-commerce websites can choose paid search advertising channels more reasonable. We developed a multivariate time series model based on the ad click-through rate and conversion rate, and calibrated the model using an e-commerce site's web logs data. We determined the long-term equilibrium relationship between each channel's ads clicks through the co-integration test and evaluated the effect of short-term fluctuations in the interaction between each channel ads clicks through the vector error correction model. Besides, we also used impulse response function to analyze the spillover effect intuitively. Through the modeling analysis, we found that the interaction between Baidu paid search ads, 360 paid search ads and Sougou paid search ads is verified, which validates the spillover

effect proposed by the research institute. Our findings can provide evidence for the company to choose the appropriate paid search advertising channels or channel combinations and have some guiding significance to this website. In the future research, we hope that on the basis of this study, we will continue to expand the relevant data such as advertising expenditures and advertising investment budgets so as to enhance the significance of the research on the actual business management. In addition, considering the heterogeneity of consumers, use data at the individual level will lead to conclusions that are more abundant.

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