

**Research Assessment Exercise 2020**  
**Impact Case Study**

**University:** Chinese University of Hong Kong  
**Unit of Assessment (UoA):** 22 Business

**Title of case study:** Towards A More Efficient Online Advertising Market: Improving Profitability for Advertisers and Search Engines

(1) **Summary of the impact** (100 words)

Sponsored search advertising is a multi-billion dollar market. Any efficiency gains in this market can result in tremendous gains in profitability. Research led by Prof. Michael Zhang has generated measurable impacts and offered important strategic insights for both the advertisers and the search engines. The main impacts were:

- For advertisers: develop strategies to bid in an optimal way, resulting in significant increase in revenue (testimonial from a company suggesting 10 million RMB of revenue so far)
- For search engines: develop models that result in, quoting Baidu's senior manager: "a substantial increase in revenue" (contributing partially to Baidu's quarterly revenue increase of 26% as reported in its quarterly financial report to the NASDAQ), and
- For online advertising market: increase the efficiency.

(2) **Underpinning research** (500 words)

Key researcher: Professor Michael Zhang (School of Business, Chinese University of Hong Kong)

Around year 2003, Prof. Zhang started research on sponsored search advertising. In the past 15 years, Prof. Zhang created a research agenda to understand how economics modeling and data analytics can help deepen our understanding on how such markets work and how research can benefit the society. These research projects recently offered fruitful impacts.

Prof. Zhang collaborated with prominent search engines such as Yahoo! and Baidu and contributed significantly to advertisers' search engine optimization. Such collaboration produced 4\* publications and working papers with potential to be published in top journals. These research projects did not end when they got published, they created opportunities for advertisers to improve bidding strategies and helped big search engines to improve their pricing mechanism and created significant value.

When the first research project (Zhang and Feng 2011, *Information Systems Research*, a 4\* journal) was conducted. The general industry perception of the sponsored search auctions was that such auctions were in a static market. Prof. Zhang's research result based on Yahoo!'s first-price auction data led to Baidu's willingness to share data to further explore the case of second-price auction. Even before the paper was published, Baidu benefited from the insight and adjusted their pricing strategy according to the results reported in this study.

The collaboration with an Enterprise Big Data Service Provider, Beijing Percent Information Technology Co., Ltd, resulted in a top publication (Du et al., 2017, *Information Systems Research*, a 4\* journal) and the result has been adopted by their Data Management Platform. About 100 clients benefited from this research and it has generated about 10 million RMB (US\$1.5 million) in economic value.

In a recent collaboration with Baidu (Shen et al., 2018, very new results, recently presented in INFORMS Annual Conference), Prof. Zhang and his colleagues developed a model of reinforcement learning to solve traditional mechanism design problems. Baidu put this research in use of their Phoenix Nest system and received significant revenue gains in the first quarter of 2018 (they report year-over-year revenue increase of 26%).

### (3) **References to the research**

- Zhang, X., and Feng, J., "Cyclical Bid Adjustments in Search-Engine Advertising," *Management Science*, 57, 9, 2011, 1703-1719.
- Du, X., Su, M., Zhang, X., and Zheng, X., "Bidding for Multiple Keywords in Sponsored Search Advertising: Keyword Categories and Match Types," *Information Systems Research*, 28(4), 2017, 711-722.
- Zhang, X., Wu, W., Xu, H., and Zheng, R., "On the inefficiency of Search-Engine Keyword Auction", 13<sup>th</sup> *Symposium of Statistical Challenges of E-Commerce Research* (SCECR), 2017.
- Shen, W., Peng, B., Zhang, X., Qian, R., Hong, Y., Guo, Z., Ding, Z., Lu, P., and Tang, P. "Reinforcement Mechanism Design, with Applications to Dynamic Pricing in Sponsored Search Auctions", *INFORMS Annual Conference*, November 2018, Phoenix, AZ, USA.

### (4) **Details of the impact (750 words)**

Prof. Zhang has a long-term relationship with key industry players in sponsored search advertising. The project started with a dataset provided by Yahoo!. After analyzing the data and developing a theoretical model, Prof. Zhang identified a dynamic equilibrium that has not been found in the literature.

Without this dynamic perspective, sponsored search advertising auctions are not well-understood by the search engines such as Yahoo!, Google and Baidu. After reading the working paper, Baidu invited Prof. Zhang to visit Baidu to explain how advertisers can bid in cyclical patterns. His talk directly influenced how Baidu models and studies advertisers. In appreciation of his contribution, Baidu shared with Prof. Zhang a dataset of second-price auction. This project later included both Yahoo!'s and Baidu's data and was published by *Management Science* (Zhang and Feng 2011). The key insights are that this market is dynamic and advertisers bid in a dynamic way, so previously used static model needs to be replaced. Once search engines can use this result, they can significantly improve their profitability because they have a deeper understanding of advertisers' behavior. As a result, the insights of this research became widely used in Baidu to give guidance to their design of auctions mechanisms.

After helping search engines to better understand advertisers, Prof. Zhang later started collaboration with a big data company, Beijing Percent Information Technology Co., Ltd., and helped this company understand search engine results better (See 5.1 and 5.2 below for testimonial). This company represents many large and medium enterprises and runs sponsored search advertising campaigns for them. This collaboration led to a publication in *Information Systems Research* (Du et al. 2017). The key insights are that advertisers should not only examine their own keywords but also should examine their competitors' keywords and strategically allocate the resources in different types of keywords. These results allowed the advertisers to save tremendous amount of advertising costs and obtain better returns on

advertising spending. After publishing this paper, the company integrated the proposed research results into their Data Management Platform (DMP). The research gave guidance to how they should allocate their advertising budget according to different types of keywords. According to the attached testimonial, this new method generated more than 10 million RMB (about HK\$12 million, or US\$1.5 million) for the company within just a year's time in 2018.

In a recent collaboration with Baidu (see testimonial in 5.3), Prof. Zhang and his colleagues developed an artificial intelligence algorithm to dynamically modify how Baidu should set the minimum bid for each keyword (Shen et al. 2018, presented at INFORMS Annual Conference). Despite Baidu's large engineering team and good knowledge of artificial intelligence, they were not able to develop economics models of mechanism design. Prof. Zhang's contribution led to very fruitful results. The key insights are that a dynamic artificial intelligence-based model can help increase the revenue for search engines, and unlike previously believed in the literature, this can be achieved even when the search engine does not have enough advertising valuation information. According to the attached testimonial, Prof. Zhang's team "helps design and optimize current price system of the Baidu ads mechanism, which leads to a substantial increase in Baidu revenue." According to Baidu's First Quarter 2018 financial report, "Baidu begins using reinforcement learning in its Phoenix Nest online marketing system, which is the first time this branch of machine learning has been implemented at Baidu." This framework refers to Prof. Zhang's project "Reinforcement Mechanism Design". Many Baidu engineers were coauthors of this project. Prof. Zhang's project contributed substantially to the revenue of Baidu Core, which was reported to have increased by 26% year over year (see 5.4 below).

#### (5) Sources to corroborate the impact

- 5.1. Company testimonial from Beijing Percent Information Technology, Co., Ltd.
- 5.2. List of clients of Beijing Percent Information Technology, Co., Ltd. who benefitted from research.
- 5.3. Company testimonial from Baidu.
- 5.4. Screenshot from Baidu First Quarter 2018 Results.<sup>1</sup>

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<sup>1</sup> <https://goo.gl/yNXRn2>