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Research article

LLM technologies and information search

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ABSTRACT

With the booming of LLM technologies (e.g., ChatGPT), people's goals and behaviors in information search have been reshaped significantly. This paper attempts to conceptually discuss how LLM technologies might revolutionize these important aspects in information search and provides a comprehensive analysis of the technological advancements and capabilities of ChatGPT, highlighting its potential to disrupt traditional search engines like Google. In addition, this paper contrasts ChatGPT's conversational approach with Google's link-based search model, offering a detailed examination of the implications for online search advertising and user behavior and explaining why Google is concerned about ChatGPT as well as its potential reactions.

1. Introduction

ChatGPT, a conversational AI chatbot from the generative pre-trained transformer (GPT) family of language models, was developed by OpenAI and released in November 2022.[1] It is based on OpenAI's GPT-3.5, GPT-4, and GPT-4o large language models (LLMs) and has been fine-tuned through both supervised and reinforcement learning techniques. ChatGPT can engage in conversational interactions and provide clear, straightforward answers across various domains of knowledge, unlike traditional search engines that simply list links.

Google, the world's leading search engine, for the first time ever, has issued a "code red" in response to the rise of ChatGPT, viewing it as a potential threat to its core business—online search advertising—and its future.[2] Google's CEO Sundar Pichai has redirected some teams to focus on AI product development, planning to unveil more than 20 new products this year. Google also has its own chatbot called Gemini, which is similar to ChatGPT and was developed by Google researchers. However, Google may be reluctant to deploy this new technology in online search, as this might cannibalize its core business (online search advertising), which accounts for most of Google's revenue.[3]

The emergence of ChatGPT and other chatbots (e.g., Claude, Bing Copilot, Perplexity) signifies a major technological shift that could disrupt the tech industry and transform how people access information on the Internet. This development also raises ethical and

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[1] OpenAI is a research lab that aims to create and promote beneficial AI for humanity (see openai.com).

[2] See ChatGPT and Other Chat Bots Are a 'Code Red' for Google Search - The New York Times (nytimes.com) and Google Management Issues 'Code Red' Over ChatGPT: Report (businessinsider.com).

[3] For more details about Google's reluctance, see https://www.bloomberg.com/news/articles/2024–04-03/google-considers-charging-for-ai-fueled-search-features-ft-says.

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social questions about AI's impact on human communication, privacy, security, and creativity. While ChatGPT and similar chatbots are still in the early stages of development and face numerous limitations and challenges, they also present new opportunities for innovation and collaboration.

This paper makes several key contributions to the understanding of how LLM technologies, such as ChatGPT, are revolutionizing information search. First, it provides a comprehensive analysis of the technological advancements and capabilities of ChatGPT, highlighting its potential to disrupt traditional search engines like Google. Second, the paper contrasts ChatGPT's conversational approach with Google's link-based search model, offering a detailed examination of the implications for online search advertising and user behavior. Third, it explores the broader economic and social impacts of ChatGPT, considering both the opportunities for innovation and the challenges related to ethics, privacy, and security. Lastly, it contextualizes these developments within relevant economic literature on information search, deliberation, digital platforms, and consumer perception and engagement, thereby contributing to ongoing academic discourse in these fields.

The remainder of this paper is organized as follows. Section 2 introduces the detailed functionality of ChatGPT and other conversational chatbots, explaining how they process information and interact with users. Section 3 discusses the specific concerns that traditional search engines (e.g., Google, Microsoft, Baidu) have regarding ChatGPT and the strategic responses they have initiated. Section 4 reviews the relevant economic literature, linking the theoretical frameworks to the practical developments discussed. Finally, Section 5 explores the future of information search in light of generative AI technologies, considering potential scenarios and their implications.

2. LLM technologies: ChatGPT and other conversational chatbots

ChatGPT is a chatbot built on GPT-3.5/4/4o (Generative Pre-trained Transformer 3.5/4/4omni) technology, designed to communicate with humans in natural language. It operates using a large neural network with 1.8 trillion parameters, trained on vast amounts of text data from the internet. This extensive training allows ChatGPT to simulate *a conversation with a human user* through text or voice on almost any topic, given some input words or sentences. In addition to ChatGPT, there are a few other popular conversational products on the market nowadays, such as Claude, Bing Copilot, Perplexity, and Gemini. A brief comparison of these products is summarized in Table 1.

ChatGPT's *dialogue format* enables users to iteratively refine their queries and explore topics in depth. It can handle various types of conversations, from casual chat to complex problem-solving, and can even generate creative content like poems or code. While ChatGPT offers many advantages, it's important to note its limitations, such as potential inaccuracies (i.e., AI Hallucinations), and occasional inconsistencies in responses.

The emergence of LLM technologies like ChatGPT marks a significant shift in how people access information. Unlike traditional search engines that provide lists of links, ChatGPT engages in conversational interactions, offering direct answers across various knowledge domains. This technological leap has profound implications for the search industry, particularly for established players like Google. The potential disruption to Google's core business model – online search advertising – has prompted a strategic re-evaluation within the company, including redirecting resources towards AI product development.

Specifically, LLM technologies like ChatGPT have the following advantages in information search over traditional search engines. First, ChatGPT offers a conversational interface that allows users to ask questions in natural language and receive detailed, context-aware responses. This contrasts with traditional search engines, which typically return a list of links. Users can engage in follow-up questions, making the search process more interactive and efficient. Second, Recent updates have enabled ChatGPT to search the web for current information, enhancing its ability to provide answers that are not limited to its training data.[4] This capability allows it to summarize content from various websites, potentially offering a more cohesive answer than traditional search engines, which present fragmented information across multiple sources.

In addition to the information search aspect, ChatGPT may revolutionize traditional online advertising on search engines. As users are increasingly looking for direct answers rather than browsing through ads and links, it could diminish the effectiveness of traditional pay-per-click advertising models.[5] Advertisers may need to adapt their strategies to engage users in a more conversational manner. In addition, OpenAI's partnership with Microsoft Bing suggests a potential integration of ChatGPT capabilities into advertising platforms, allowing for more personalized ad experiences.[6] This could lead to more targeted advertising based on user interactions with AI, providing advertisers with richer data on consumer preferences and behaviors. Furthermore, the rise of AI-driven search tools like ChatGPT may necessitate a reevaluation of search engine optimization (SEO) strategies. Businesses may need to focus more on creating content that is easily understood and relevant to conversational queries, rather than solely optimizing for keyword-based searches.

3. Impact on traditional search engines: Google's concerns and reactions

Google is concerned about ChatGPT because it threatens its core business—online search advertising—and its future. Google generates the majority of its revenue from selling ads on its own platforms, such as Google Search, YouTube, Gmail, and Google Maps,

[4] For more details, see https://openai.com/index/searchgpt-prototype/.

[5] For example, consumers may be able to purchase products directly through ChatGPT without having to visit a brand's or retailer's website.

[6] ChatGPT has been integrated with Bing, Microsoft's search engine. Users can join a waitlist to use Bing with ChatGPT and get personalized and conversational search results. Bing with ChatGPT can also help users with tasks such as booking flights, finding restaurants, or learning languages.

Table 1
Comparison of conversational chatbots.

Product	Company	LLM technology	Key Strength
ChatGPT	OpenAI	GPT 3.5/4/4o	Versatility, general knowledge
Claude	Anthropic	Claude 3 (Opus, Sonnet, Haiku)	Strong performance on complex tasks
Bing Copilot	Microsoft	GPT 3.5/4/4o	Combination of search and AI capabilities
Perplexity	Perplexity	GPT 3.5/4/4o, Claude 3	Online, up-to-date answers
Gemini	Google	Gemini 1.5	Integration with Google ecosystem

as well as on third-party websites and apps that use Google's advertising services, such as Google Ads and Google AdSense. According to its 2023 annual report, Google's advertising revenue was $237.9 billion, accounting for 77 % of its total revenue.[7]

For example, users can use Google Search to find information on the Internet by entering keywords or queries. Google's search engine returns a list of links to web pages that are relevant to the user's query, ranked by their popularity and authority. At the top of these links, Google displays ads, which generate income for Google and its advertisers. Fig. 1 illustrates Lenovo's sponsored ads (after entering "laptop") on Google.

AI chatbots like ChatGPT, however, offer a new way to search for information on the internet, which may challenge Google's search engine. Instead of entering keywords or queries, users could interact with AI chatbots in natural language and receive information in clear and simple sentences. AI chatbots could also provide more personalized and engaging responses than Google's search engine, by adapting to the user's preferences, interests, and emotions. In addition, the chatbot could also generate new information or content that Google's search engine may not have access to or be able to provide. Figs. 2 and 3 illustrate the dialogue format of information interaction of Perplexity and ChatGPT (offered by Microsoft's New Bing).

From Figs. 1–3, one can have the following evident observations about several key differences between AI chatbots and Google's search engine. First, AI chatbots offer a dialogue-based interaction process whereas Google provides a list of relevant links based on the users' query, ranked by their popularity and authority. Second, users can easily use AI chatbots' conversational interactions to deliberate their information needs and evaluate the value of information, while they have to costly click and read various web pages in Google's search results. Third, although sponsored ads appear on both Microsoft's New Bing (backed by GPT) and Google, the sponsored ads on Microsoft's New Bing appear after multiple iterations of information exchange when the AI chatbot collects sufficient information from the author and knows him better (i.e., entering "laptop", "which laptop is best for gaming?", and "how much do these laptops cost?"). However, sponsored ads show up on the very top of Google's search results right after the author enters the keyword "laptop".

With these advantages, AI chatbots like ChatGPT may become widely adopted and preferred by users over Google's search engine, potentially causing Google to lose market share and revenue in the online search industry. Google could also lose its competitive edge and influence in the tech industry and society at large.

Google is aware of the potential threat posed by ChatGPT and other chatbots, and it is taking steps to actively respond to the challenge. Google's CEO Sundar Pichai has issued a "code red" over the rise of ChatGPT, indicating an emergency that requires immediate action. Google has redirected some teams to focus on developing AI products that can compete with or complement ChatGPT. In particular, Google has introduced Bard, a conversational AI service initially limited in availability, which has since evolved into Gemini. This AI system is designed to provide users with conversational responses and is integrated into Google's search engine. Google aims to combine traditional search results with AI-generated summaries to improve the relevance and immediacy of information presented to users. Fig. 4 illustrates how Gemini interacts with the author. Obviously, Gemini also adopts a form of conversational interaction similar to ChatGPT, and it also makes full use of its own Google ecological advantages to integrate Google web links into the conversations, which is exactly the same as Perplexity.

In addition to Google, other traditional search engine companies have also responded quickly to the rise of LLM technologies like ChatGPT. Microsoft has taken a proactive approach by launching Bing Chat, later rebranded as Copilot, which utilizes OpenAI's technology. This integration has led to a notable increase in Bing's search ad revenue, which is expected to grow significantly faster than Google's as more users adopt AI tools for search.[8] The company is leveraging its existing platforms, including Microsoft 365, to embed AI functionalities that enhance user interaction with search. Besides, Baidu, the leading search engine in China, has also entered the AI space with its service called Ernie. This AI-powered chat service aims to provide similar functionalities to those of Google and Microsoft, reflecting a global trend among search engines to adopt AI technologies to meet user demands for more efficient information retrieval.

[7] Google also has other businesses that contribute to its revenue and growth, such as cloud computing, hardware, and other bets. Google's cloud computing business includes Google Cloud Platform, which offers infrastructure and data analytics services, and Google Workspace, which offers productivity and collaboration tools. Google's hardware business includes devices such as Pixel phones, Nest smart home products, Chromebooks, and Chromecast. Google's other bets are long-term, risky, and potentially disruptive projects that aim to create new markets and technologies, such as Waymo (self-driving cars), Verily (life sciences), Loon (internet balloons), and Wing (drone delivery).

[8] For more details, see https://www.impressiondigital.com/blog/bing-differ-google/.

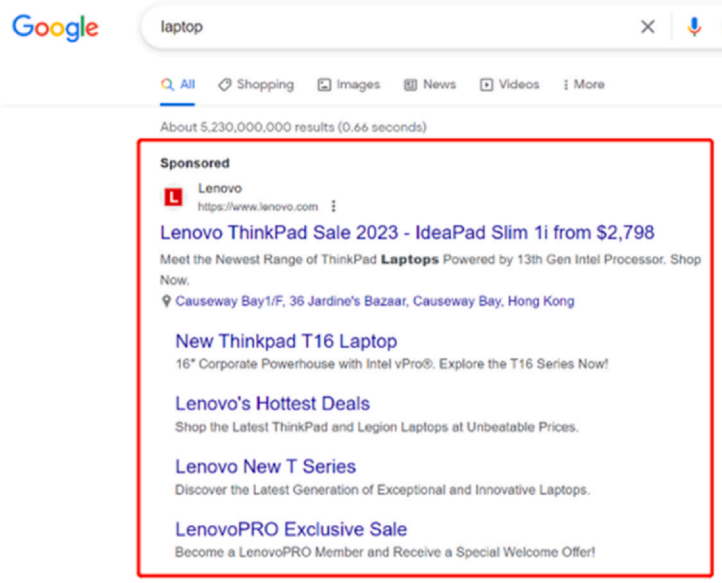

Fig. 1. Sponsored Ads from Lenovo on Google.

4. Relevant literature

The above discussions are generally related to four key streams of economic literature: search, deliberation, digital platform, and consumer perception and engagement.

First, the paper is related to the literature on information search (Wolinsky, 1986, Anderson and Renault, 1999, Liu and Dukes, 2013, Liu and Wang, 2023, Zhang et al., 2024). Specifically, there are two types of mainstream search models: parallel search and sequential search, which differ in how people collect and evaluate information. Under parallel search, individuals first select a sampling plan, doggedly evaluate all alternatives in the plan, and then select the best alternative after evaluation (provided that doing so is better than choosing the no-select option which is usually assumed to provide zero utility). Many studies use parallel search model to capture people's search behavior (e.g., Morgan and Manning, 1982, Chade and Smith, 2006, Kircher, 2009, Liu and Dukes, 2013, 2016, Dukes and Liu, 2016, Liu and Wang, 2021).[9]

Different from parallel search, under sequential search, people evaluate alternatives one by one until finding a desirable alternative and thus quitting the search process (e.g., Wolinsky, 1986, Anderson and Renault, 1999, Armstrong et al., 2009, Menzio and Trachter, 2015, Liu et al., 2022, Jin et al., 2022, Liu and Wang, 2023). Specifically, in the sequential search process, a person's search behavior is guided by an optimal stopping rule which dictates whether she should pick the alternative immediately (and thus quit searching) or keep on searching the next alternative.[10]

LLM technologies like ChatGPT might fundamentally reshape the landscape of information search. In the context of search theory, LLMs introduce a novel paradigm that challenges traditional models of both parallel and sequential search. Unlike conventional search engines that require users to sift through multiple results, LLMs offer a conversational interface that can provide direct, summary answers. This approach potentially reduces search costs and alters the optimal search strategy for users. In addition, the conversational interaction form of LLM may transform the previously common sequential search based on web links into the parallel search based on the consideration set formed by the dialogue.

The second related strand of literature is deliberation, which examines how people make choices when they must invest significant time and resources to understand their own tastes (Shugan, 1980, Kahn and Meyer, 1991, Wathieu and Bertini, 2007, Guo and Zhang, 2012, Xiong and Chen, 2013, Guo, 2016, Li et al., 2019, Xu and Zhou, 2021). The key difference between deliberation and search is as follows. Under deliberation, people do not know their inherent tastes and thus must costly invest effort to understand

[9] Notably, parallel search is often used in explore people's consideration set formation (Morgan and Manning, 1985, Dukes and Liu, 2016). For example, when buying a mid-size SUV, a consumer might consider all models of Mercedes and BMW before making her purchase. In this example, all mid-size SUV models of these two German brands constitute the consumer's consideration set (i.e., sampling plan). When forming the consideration set, the consumer will balance the expected benefits of evaluating all mid-size SUV models of the two brands and the associated search costs. That is, all benefits and costs are current when the consideration set is formed.

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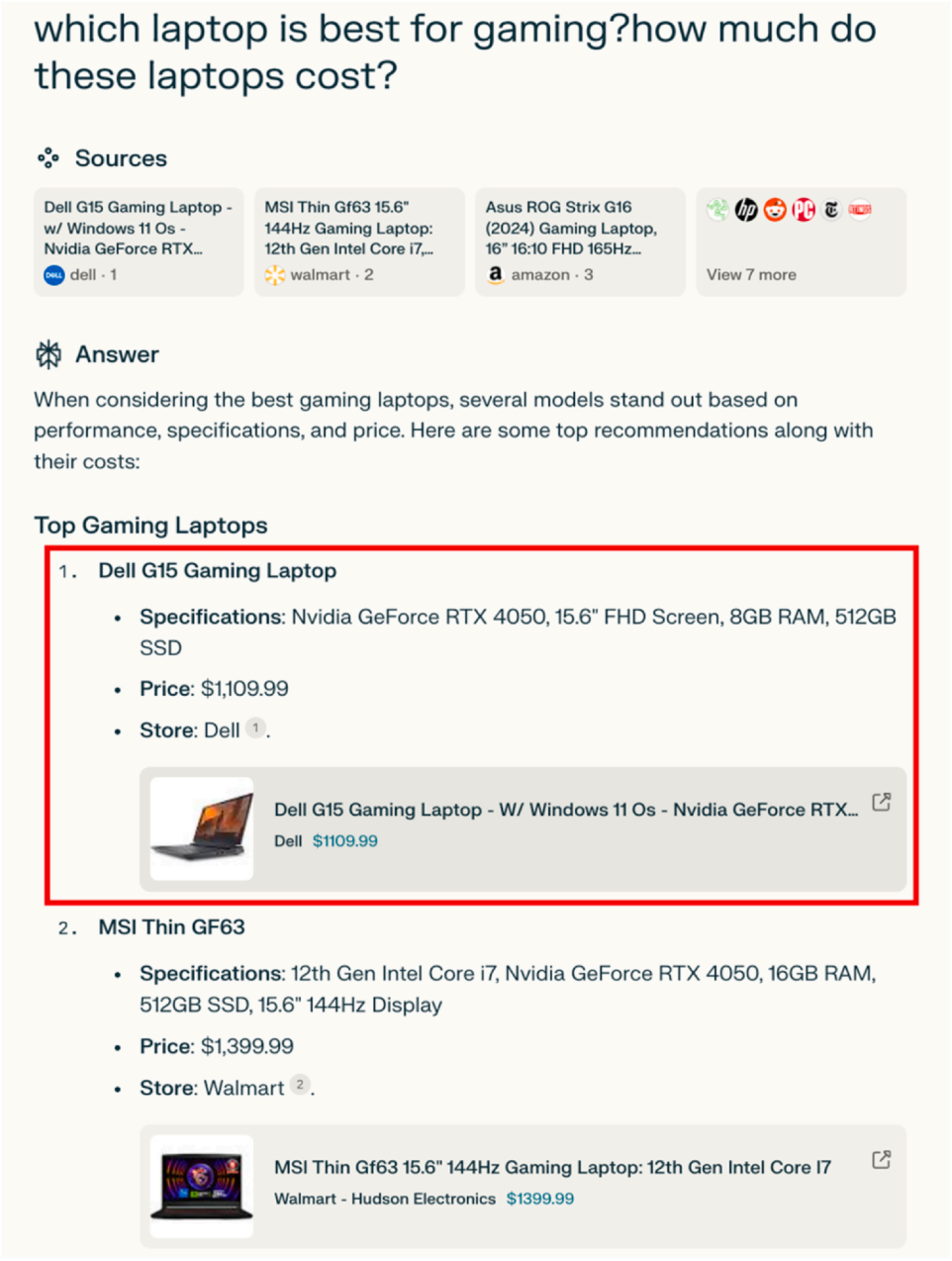

Fig. 2. Sponsored Ads from Dell on Perplexity.

their own nature. In contrast, under search, people know their inherent tastes but face uncertainty about the attributes of alternatives and thus have to costly evaluate the nature of alternatives.

For example, consider a consumer buying a car. She might have uncertainty about her tastes and the value of different vehicle models, and thus, her purchase process is a series of interactions between deliberation and search. Specifically, she might not know about what kind of car she likes, an SUV or a sedan. After visiting different car dealers and test-driving various cars, she figures that a sporty car is her taste (*deliberation—figuring tastes*), and then focuses her search on SUVs. She knows that a mid-size car fits her needs but she is uncertain which brand provides a mid-size SUV, and thus, she needs to costly search this information through Google (*search—figuring attributes*). After narrowing down to several brands (e.g., Mercedes and BMW), she might be uncertain about what color she loves the most. After trying different models, she figures that the white color is her taste (*deliberation—figuring tastes*). She then focuses on evaluating and comparing white mid-size SUVs of Mercedes and BMW and buys the one that best fits her tastes (*search—figuring attributes*).

Obviously, LLMs can act as intelligent intermediaries in the deliberation process, potentially helping users clarify their own tastes and preferences through iterative conversations. This connection is particularly prominent in complex decision-making scenarios

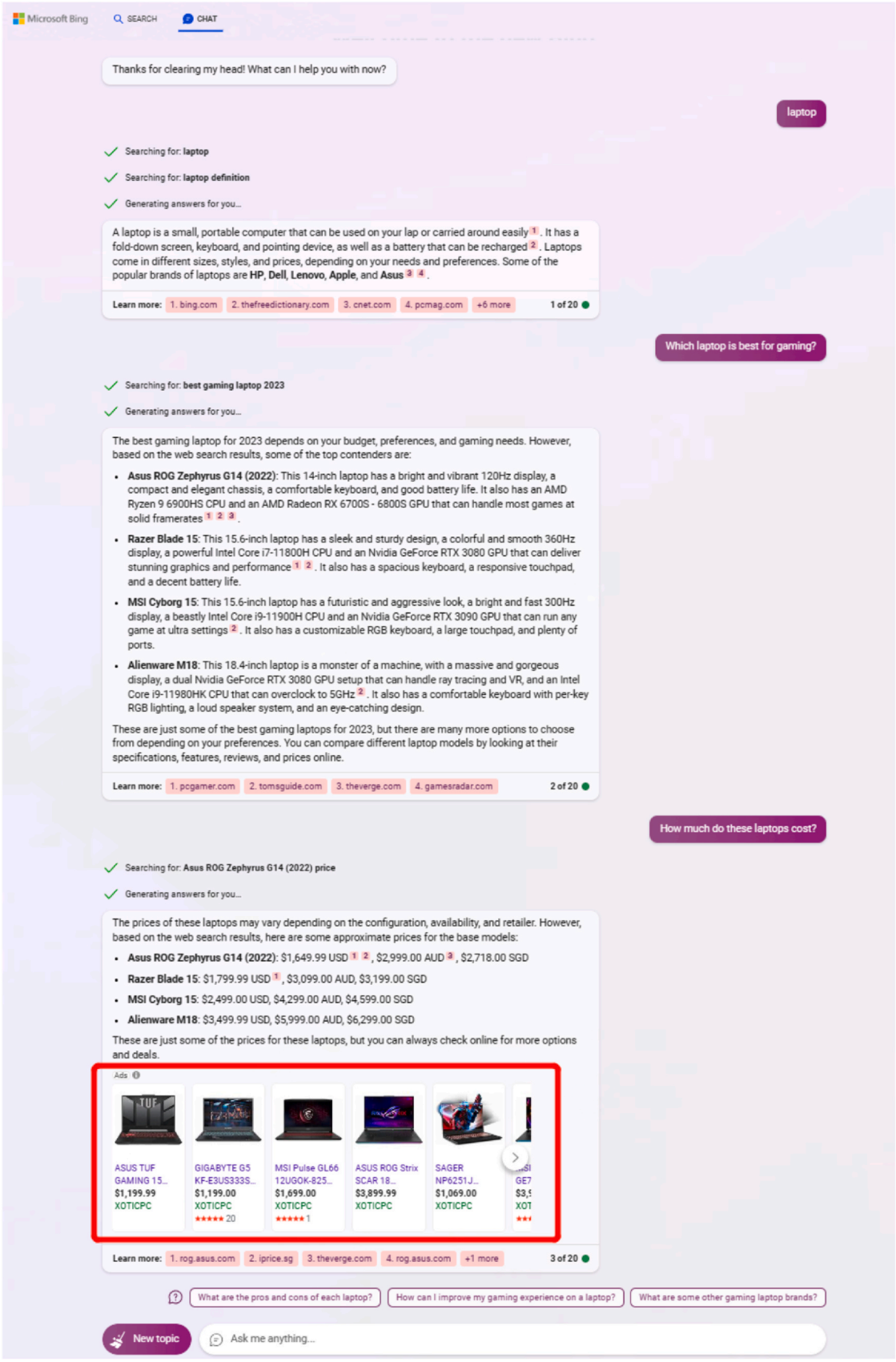

Fig. 3. Sponsored Ads from Xoticpc on ChatGPT (by Microsoft's New Bing).

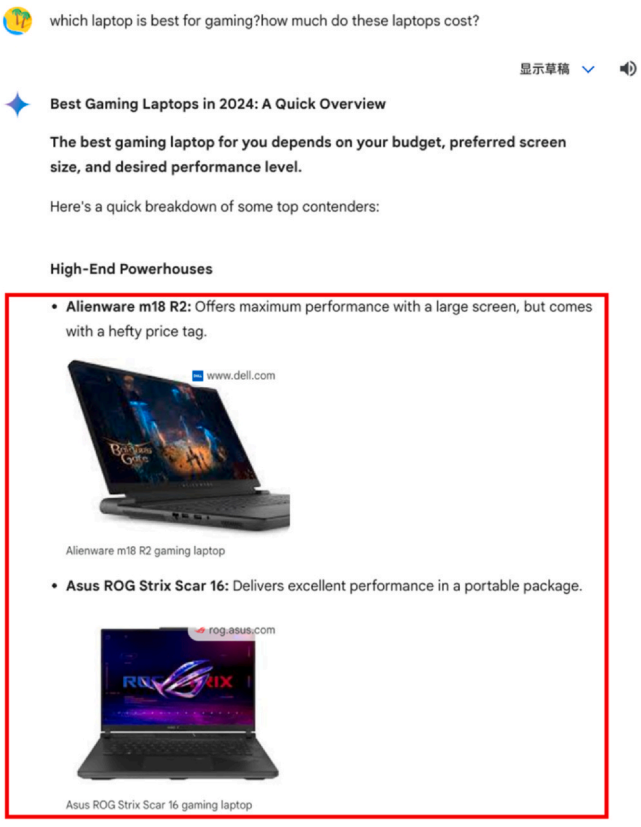

Fig. 4. Sponsored Ads from Dell and ASUS on Gemini.

where users might be uncertain about their own needs or desires. By offering contextual information, suggestions, and clarifications, LLMs could significantly reduce the cognitive load associated with deliberation, potentially leading to more informed and satisfying decisions.

The third related strand of literature is the digital platform. Digital platforms are online structures that enable the exchange of goods, services, and information between users and providers (Rochet and Tirole, 2003, Laffont et al., 2003, Caillaud and Jullien, 2003, Baye and Morgan, 2001, Zhang et al., 2022, Zhong, 2023, Leong et al., 2024). Digital platforms have dramatically transformed the landscape of information search and retrieval, impacting both economic models and user behavior. Traditional digital platforms like Google have dominated the market by leveraging network effects and data-driven personalization, creating an efficient yet traditional search experience where users input queries and receive a ranked list of links. Nevertheless, LLMs introduce a new dimension to this ecosystem by offering highly personalized, conversational interactions that could create novel forms of user engagement and loyalty. This shift could alter the nature of competition among digital platforms, potentially creating new winners and losers based on the quality and capabilities of their LLM integrations. Moreover, LLMs could change the way platforms monetize user interactions, particularly in the field of online advertising, by offering more nuanced and context-aware opportunities for user-advertisement matching.

Specifically, compared to Google, ChatGPT's conversational interactions provide a healthier information discovery process in which users can easily conduct multiple iterations to deliberate their inherent needs for information and evaluate the value of information (including attributes). That is, if users are rational decision-makers whose choices are made based on the maximization of the difference between expected benefits and costs, they are likely to use ChatGPT's dialogue format of interactions over Google's stuff list of links like traditional search results.

The fourth related strand of literature is consumer perception and engagement. Consumer perception, as studied by Zeithaml (1988), Parasuraman et al. (1985), and Fatma and Rahman (2017), focuses on how consumers interpret and evaluate information and experiences. In the process of information search, perception plays a key role in how users assess the credibility, relevance, and quality of information sources. Consumer engagement, on the other hand, has been extensively studied in the context of digital platforms and social media. Brodie et al. (2013) define consumer engagement as a psychological state that occurs through interactive experiences with a focal agent or object. In the digital age, engagement often manifests as user-generated content, feedback, and active participation in online communities (Van Doorn et al., 2010).

LLM technology introduces novel dimensions to both consumer perception and engagement.[11] In terms of perception, LLMs fundamentally alter how users interact with and perceive information sources. Unlike traditional search engines that present a list of potentially relevant links, LLMs offer direct, conversational responses. This shift may influence users' perceptions of information credibility and relevance, as they interact with an AI that appears to "understand" their queries and provide contextual responses. The conversational nature of LLMs may also affect users' perception of the search process itself, potentially making it feel more intuitive. Regarding engagement, LLMs create unprecedented opportunities for users to contribute to and shape the information landscape. Every interaction with an LLM can be seen as a form of engagement that potentially improves the system's responses for future queries. Moreover, the iterative nature of LLM interactions allows for a depth of engagement not typically seen in traditional search, potentially leading to more satisfied users. This dynamic engagement could have significant implications for how digital platforms design their user experiences and build user loyalty in the age of LLM-powered information search.

5. ChatGPT and the future of information

The future of information will likely be significantly influenced by ChatGPT and other generative AI technologies in various ways. For example, ChatGPT could revolutionize the economy by automating many tasks that require human creativity and reasoning, such as writing, data analysis, customer service, education, and entertainment. It could transform healthcare by providing accurate diagnoses, personalized treatments, and health education to patients and providers. ChatGPT could enhance communication by supporting multiple languages, generating summaries and translations, and creating engaging content for social media and marketing. However, the integration of ChatGPT also poses challenges and risks, including ethical issues, social implications, data quality, security, and accountability.

ChatGPT has a wide range of applications and influences in various industries. ChatGPT's dialogue format has enabled scientists to converse with AI to generate potential drug targets.[12] For example, drug discovery companies are customizing ChatGPT to interact with their other AI and machine learning tools, such as target discovery platforms, knowledge graphs, and computational chemistry models. ChatGPT can also answer medical questions using Med-PaLM, a chatbot designed by Google and DeepMind. In addition, the AI chatbot can also assist lawyers by identifying themes, patterns, or topics in large sets of documents, prioritizing and categorizing documents based on their relevance to the case, finding key concepts, entities, and relationships within documents, summarizing documents, generate queries, and more.[13]

While debates continue over the pros and cons of ChatGPT versus Google,[14] and despite the limitations and uncertainties of these developing technologies, generative AI holds great potential to transform the way we access, produce, and consume information in the future. The following propositions outline potential future research directions to explore the impact of LLMs in business contexts:

i. LLMs will significantly reduce search costs, leading to more efficient information markets. Future research could examine how these reduced costs affect consumer surplus and firms' strategies.
ii. LLMs will alter the nature of consumer deliberation, potentially leading to more informed and less costly decision-making. An interesting area for further study is how LLM-assisted deliberation impacts consumer choices and firms' strategic responses.
iii. LLMs will reshape online advertising competition on digital platforms. Future research might explore how firms use LLMs for personalized advertising and pricing strategies.
iv. LLM-powered information search will change consumers' perception of information credibility and relevance compared to traditional methods. A potential research direction could investigate how interactions with LLMs affect users' trust and evaluation of information sources.
v. LLMs will increase consumer engagement by enabling more interactive and personalized information experiences. Further research could assess the extent to which LLM-powered interactions enhance user engagement compared to traditional digital interfaces.

Future research is necessary to test the theoretical and empirical validity of these propositions, which will deepen our understanding of the transformative potential of LLMs like ChatGPT in business and beyond. Moreover, future research can also focus on a series of key role of ChatGPT and generative AI on information, such as information accessibility and understandability for users who

[11] Traditional user engagement can be measured by tracking metrics such as average session duration, bounce rate, page views, user retention rates, and interaction with content like clicks, likes, and shares.

[12] See https://www.sciencedaily.com/releases/2024/02/240207195142.htm.

[13] See https://rankings.io/blog/chat-gpt-for-lawyers.

[14] For example, ChatGPT and Google have different goals and use cases. ChatGPT may be more suitable for creative or personal tasks, such as writing poems, jokes, or stories, while Google may be more suitable for factual or professional tasks, such as finding news, data, or products. ChatGPT can produce human-like text that is engaging and entertaining, but it can also make up facts or be inconsistent. Google can provide accurate and reliable information from various sources, but it can also be biased or incomplete. ChatGPT may be more appealing for users who want to have fun or explore ideas, while Google may be more appealing for users who want to get answers or solve problems. In addition, ChatGPT is a relatively new product that is still in development and has limited access. Google is a well-established product that is widely used and integrated with other services and platforms. ChatGPT may face challenges in scaling up, ensuring safety and quality, and gaining user trust and loyalty. Google may face challenges in innovating, adapting, and competing with new technologies and competitors.

have low literacy skills or language barriers; personalized and engaging responses for users by adapting to their preferences, interests and emotions; new information or content generation for poems, stories, code and images; creativity and innovation facilitation among users by inspiring them with new ideas and suggestions; communication and collaboration among users by connecting them with people who share similar interests or goals; education and learning enhancement among users by providing them with explanations, feedback and guidance; dealing with the privacy violation and security concerns of users; the quality and reliability improvement of information for users by producing texts that are accurate, relevant or unbiased; authority and credibility of information sources selection for users; texts generation that are indistinguishable from human-written texts; avoiding AI manipulation or deception on humans.

Declaration of Competing Interest

Yongliang Yang is an Associate Editor and Lin Liu is the Editor-in-Chief for the *Journal of Economy and Technology* and were not involved in the editorial review or the decision to publish this article. All the authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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