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Regulating online search in the EU: From the android case to the digital markets act and digital services act☆

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ABSTRACT

This paper offers an analysis of the impacts of public regulations of internet search. Through a theoretical model, we consider three regulations adopted by the EU. The first is the Android choice screen implemented in the European Economic Area in 2020. The other two are the recently adopted Digital Markets Act (DMA) and Digital Services Act (DSA). We find that interventions involving user choice, like the Android choice screen, can be strengthened by other interventions focused on search engine quality and data portability. Since the regulations in the DMA target these multiple dimensions simultaneously, we expect it to deliver the strongest and most effective impacts on the online search market. We also argue that the impacts of the regulations may vary over different time horizons: when first implemented, the DSA may simply direct users to search engines with better privacy protection, but over time it has the potential to change user tastes for privacy and, hence, drive search engines to invest more in privacy protection.

1. Introduction

The prevalence of the internet has endowed us with more accessible information and great convenience. However, the overwhelming amount of information also makes us more dependent on search engines for information filtering and collection. By 2021, the number of worldwide internet users had reached 4.72 billion. Of these, Google accounts for up to 4.3 billion, carrying a market share of 92.24%.[1] Each day, around 9 billion searches are made on Google, meaning that each person on average makes 3 or 4 Google searches.[2] As of 2020, Google's parent company generated $161.9 billion in revenue,[3] which equals nearly one-third of Belgium's 2019 GDP and even surpasses that of Hungary.[4] The rapid growth of Google should partly be credited to the network effects in the online search market: the large mass of users on Google endows the firm with more available data and certain economies of scale,

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[1] See https://www.semrush.com/blog/google-search-statistics/.
[2] See https://earthweb.com/how-many-google-searches-per-day/.
[3] See https://www.visualcapitalist.com/how-big-tech-makes-their-billions-2020/.
[4] See https://statisticstimes.com/economy/european-union-countries-by-gdp.php.

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resulting in potentially superior search algorithms and lower operating costs. These advantages induced by the large mass of users on Google can increase the difficulty for rivals to compete with this gatekeeper company.

This increasing concentration in the online search market has induced antitrust concerns (see Scott Morton and Dinielli, 2020 and Motta et al., 2022). Regulators are worried that Google's dominant position may generate comparative disadvantages and entry barriers that other search engines struggle to conquer. This can in turn affect advertising, product prices, and sales.[5] To restore competition, the European Commission (EC) has made legislative proposals and brought various antitrust cases. In March 2020, the EC and Google reached an agreement to provide a choice screen on all new Android mobile devices shipped to the European Economic Area (EEA) and the UK, through which users can choose their preferred default search engine between Google and other alternatives. Before the intervention, Google was automatically pre-installed as the default search engine on all Android devices in Europe. Recently, new regulations and rules for digital platforms have also been approved by the EC and will be implemented in 2024 with the Digital Markets Act (DMA) and the Digital Services Act (DSA).

Despite the intense debate and considerable efforts by the regulators, a comprehensive investigation of all the regulatory interventions proposed by the EC and their likely impacts on the online search market is absent. To fill the gap, this paper incorporates the prominent features of the online search market in a simple theoretical framework. Users in our model prefer to use search engines that already have large existing user bases. This is, using the terminology of Belleflamme and Peitz (2019), an example of positive within-group network effects. Some users are captive to Google due to behavioral bias, meaning that they do not consider other alternatives. Since most search engines do not charge cash prices to users, our model also allows users to have limited awareness of the non-cash price, namely, the value of their information collected and monetized by the search engines by selling advertising. By integrating the recent regulations within the model, we then investigate the potential combined impacts of all the EC's recent interventions on the online search market. Considering that all factors do not play out simultaneously, we discuss their likely influence in the short run and in the long run, respectively.

We begin our analysis by studying the Android choice screen in the EEA, which was preceded by the EC's investigation of Google's illegal contractual restrictions for Android device manufacturers. The main goal of the choice screen is to diminish Google's position as the default search engine and increase the number of users considering other search engines. Our model shows that motivating more users to consider other search engines can reduce Google's market share while benefiting competing search engines in the short run. In the long run, when search engines have sufficient time to adjust their design strategy regarding how much value is extracted from users, it provokes conflicting effects. Although having fewer users locked in Google increases the demand for competing search engines, the more competitive market also motivates Google to diminish the value extracted from its users and makes it more favorable in the long run. Precisely, there exists a quality threshold $\overline{v}_j$ such that the choice screen increases the demand for a competing search engine only if its quality is higher than $\overline{v}_j$. This finding is in line with recent analysis (see Ostrovsky, 2021 and Decarolis et al., 2022), which also highlights the importance of the rival's quality and mechanism design in determining the impacts of the choice screen.

We then extend our analysis to the DMA, the main goal of which is to ensure fairer and more contestable digital markets. The regulations in the DMA can be generally categorized into three dimensions. First, the DMA aims to increase the number of users considering alternatives to Google, just like the Android choice screen. To give a few examples, new regulations in the DMA forbid Google from preventing end users from switching to rivals, ensure users have the freedom to change default search engines on their devices, and prohibit Google from treating its product more favorably in search results rankings. Second, there are regulations in the DMA that assist competing search engines to enhance their service quality. For instance, Google is required by the DMA to provide effective interoperability with other firms, meaning that the company can no longer practice self-preferencing by providing inferior ancillary ad technology to competing search engines. Third, the DMA improves data portability across search engines. This includes a requirement that Google provides other search engines with access on fair, reasonable, and non-discriminatory terms to ranking, query, click and view data. As search engines rely heavily on available data to train their algorithms, data sharing can help them also to benefit from the gatekeeper's dominant network size.

Our model shows the impacts of regulations in these three dimensions are interdependent and mutually reinforcing. Since only search engines with sufficiently high quality can gain market share from having more potential users consider them, helping search engines to enhance their quality fosters more search engines to be "qualified" challengers to Google. Furthermore, we also find the quality threshold $\overline{v}_j$, beyond which a competing search engine can effectively challenge Google, is also decreasing in the data portability across search engines. Therefore, improved data portability allows more search engines to be sufficiently qualified to attract users away from Google. In other words, regulations on quality improvement and data portability are both expected to strengthen the impact of regulations increasing the number of potential users of competing search engines. Consequently, we expect the DMA to deliver stronger and more effective impacts on the online search market than the Android choice screen.

Lastly, we study the regulations in the DSA. With regards to the online search market, the most related interventions in the DSA concern search engines' transparency obligations. Most search engines do not charge cash prices to users, so it is difficult for users to accurately determine how much value is extracted by search engines. To fix this issue, the DSA requires all search engines, especially the very large ones, to ensure their users can always clearly identify why they have been targeted by specific advertisements. This means Google has the responsibility to make its algorithmic processes clear to users. Additionally, it must guarantee that key data is accessible to researchers with the intention of comprehending the progression of online risks.[6] These new regulations are expected to

[5] Numerous existing research studies the impact of advertising on product price and sales (e.g. Leone, 1995; Milyo and Waldfogel, 1999, and Genesove and Simhon, 2015).

[6] See https://www.searchenginejournal.com/digital-services-act-overview/447789/.

enhance users' awareness of the information that is collected and monetized by search engines. In the short run, this will direct users to search engines with better privacy protection. In the long run, its impact will be much more profound. The change in users' tastes may generate stronger motivations for search engines to invest in privacy protection.

Through the analysis, we remind policymakers to be cautious about the following facts. First, the impact of an intervention in the short run can be quite different from its long run impact. It is important to keep in mind that search engines can adjust their strategy in response to the interventions. The network sizes of search engines in the long run are not fixed. Therefore, when curtailing the dominant position of the current gatekeepers, regulators need to be prudent in preventing new gatekeepers from emerging in the industry. Second, the impacts of interventions are not independent. Interventions that aim at one dimension can influence the impact of interventions working on a different dimension. As illustrated in our study, the impact of reducing captive users locked in Google is jointly determined by the search engine quality and data portability in the market. To effectively restore competition, regulators should be careful in designing interventions.

Literature Review This paper is mainly built upon the following strands of literature. First, our work is inspired by the research in markets with multi-sided platforms, where two or more distinct groups interact via a platform and generate value from these interactions (Belleflamme et al., 2020). Rochet and Tirole (2006) and Rysman (2009) provide cornerstones to this growing literature. Armstrong (2006) illustrates whether and how the relative magnitudes of network effects determine platforms' pricing strategies. Yoo et al. (2002) point out the critical role of switching costs and the strength of network effects in determining users' strategy. Parker and Van Alstyne (2005) demonstrate network effects as the underlying motivations for a firm to invest in a product and then give it away in perpetuity.

The majority of the studies of multi-sided markets (Rochet and Tirole, 2004; Jullien, 2005; Armstrong, 2006) focus on positive cross-group network effects, whereby users benefit from the increased participation of other groups. For example, advertisers favor search engines with numerous users, sellers are drawn to marketplaces with a multitude of potential buyers, and buyers are attracted to markets offering a wide product variety. Nevertheless, cross-group network effects may not always be positive. Additionally, a user's surplus from participating in a market could be also influenced by the presence of other users in the same group (Belleflamme and Toulemonde, 2009; Belleflamme and Peitz, 2019). Take, for instance, a user selecting a search engine. They might not care about or might dislike encountering advertisements on a website, but normally opt for search engines with a larger user base as they often appear to offer superior search quality. Built upon existing research (Katz and Shapiro, 1985; 1986; De Palma and Leruth, 1996; Crémer et al., 2000), our paper seeks to introduce this "within-group" network effect into the platform economy.

Since the paper discusses users' limited awareness of fees on digital platforms, it is also naturally linked to studies on shrouded fees on digital platforms (Dahremöller, 2013; Heidhues et al., 2016; Murooka, 2015). Shrouded fees are especially prevalent in the online search industry, as some users underestimate the value extracted by search engines. Gabaix and Laibson (2006) show that informational shrouding even flourishes in highly competitive markets, in markets with costless advertising, and when the shrouding generates allocational inefficiencies. Gomes and Tirole (2018) discuss how mandating price transparency and banning loss-making affects a market with users that are heterogeneous in sophistication. Our study also incorporates other prominent phenomena in digital markets. For instance, we consider the possibility that users may be captive to some platforms due to behavioral bias. Therefore, the paper is also naturally related to recent progress in behavioral economics, especially the studies of how default option influences users' choice. Seminal papers in this field are: Chetty (2015), Madrian and Shea (2001), Marzilli Ericson (2014), Ho et al. (2017), Handel (2013), and Grubb (2015). As pointed out by Beshears et al. (2018), default bias is a behavioral bias such that the current state of affairs is preferred by users. This behavioral bias becomes especially influential when inertia presents in users' behavior and prevents users from applying their preference rankings to available alternatives (Spiegler, 2011).

Lastly, our paper is related to antitrust analysis in digital markets (Sidak, 2001; Nalebuff, 2004; Tirole, 2005; Cheng and Nahm, 2007; Carlton et al., 2010; Dubé et al., 2010; Calvano and Polo, 2021), especially of tying, bundling, and competition. As pointed out by Gans (2011), pre-installation is a special form of tying that affects consumer willingness to pay for a rival's complementary goods and transfers profits from the rival to the monopolist. Similar cases brought against Microsoft induced much research (Economides and Lianos, 2010; Ayres and Nalebuff, 2005; Vásquez Duque, 2021) on choice screen and tying. Among them, the most recent paper by Ostrovsky (2020) conducts a theoretical analysis of the auction mechanism characterizing the initial implementation of the choice screen adopted by Google in the EEA.

The rest of the paper is organized as follows. In Section 2, we introduce the market features and the institutional background of regulations in the online search market. Based on the market characteristics, we then present a conceptual model in Section 3 and provide comparative statics to shed light on recent regulations in Section 4. Lastly, we extend our analysis to discuss multihoming users and information value in Section 5 and conclude in Section 6.

2. Institutional background

2.1. Market features

Internet search represents a fundamental type of digital service that allows users to easily access the information spread across the web and, through targeted advertising, fosters the ability of firms to reach potential customers. Without any intention to offer a complete discussion of the complex institutional characteristics of internet search, in this section we summarize three features that are of particular relevance for the analysis that will follow.[7]

First, the large mass of Google users has made it popular among advertisers and, through that, endowed it with the financial resources needed to support investments in its technology and services. Therefore, Google can maintain up-to-date search results by operating extensive web crawling and indexing. According to a recent survey[8], Google indexes hundreds of billions of web pages on average, while Microsoft Bing, in comparison, is estimated to index between 8 and 14 billion web pages. Nevertheless, these two companies utilize different criteria for page indexing, resulting in Bing potentially indexing a larger quantity of pages than Google pertaining to specific topics or classifications.[9] Other general search engines, like DuckDuckGo, Ecosia, and Qwant, cannot afford independent web crawling and rely on Bing to provide complementary search results.

Second, Google's large user base provides it with massive first-hand "click-and-query" data. These "click-and-query" data contain information about the terms users search for and how users respond to the search results. By learning and processing the data, search engines identify and test potential improvements in their future search results. Thus, search engines with more users enjoy a more complete data set and higher search accuracy.

Third, Google is active, and often dominant, at nearly all levels of the online advertising supply chain. For instance, it runs the marketing platform Display & Video 360 (DV 360) for managing online display ads, the ad server DoubleClick for Publishers (DFP), and the ad exchange platform AdX connecting publishers and advertisers. The last two technologies are under the brand of Google Ad Manager, which is estimated by the CMA to account for more than 90% of the display advertisements served in the UK.[10] As pointed out by executive Vice-President Margrethe Vestager: "Online advertising services are at the heart of how Google and publishers monetize their online services. Google collects data to be used for targeted advertising purposes, sells advertising space, and also acts as an online advertising intermediary. So Google is present at almost all levels of the supply chain for online advertising." This allows Google to access considerable information about its competitors, which it can then use to compete against them. Also, by bundling or self-preferencing its products or services, Google can easily foreclose competitors and give prominence to its own services within its ecosystem.

2.2. *Android choice screen*

In July 2018, the EC fined Google € 4.34 billion for imposing illegal restrictions on Android device manufacturers and mobile network operators. Google was found to be offering its Play Store, Search App, and Chrome Browser as a bundle.[11] Since Play Store critically determines the value of Android devices, this bundling left manufacturers with no choice but to pre-install Google as the default search engine on their devices. This, in turn, has enabled Google to occupy the majority of entry channels for search queries. The EC concluded that Google's conduct had distorted market competition.

Under an agreement with the EC, Google introduced a choice screen in March 2020.[12] The choice screen appears in the initial setup of all new Android phones and tablets shipped in the EEA and the UK. Users were able to select their preferred search engine among four different search providers exhibited on the choice screen. More specifically, choosing a search provider on the choice screen, as originally devised, would (i) set the search provider in a home screen search box; (ii) set the search provider as Chrome's default search engine if Google Chrome is installed; and (iii) download the search app of the selected provider. A quarterly auction in each EEA member state determined the list of search providers displayed on the choice screen. During the auction process, search providers bid the amount they were willing to pay Google each time a user selected them from the choice screen. The three highest bidders, along with Google, would appear in a random sequence on the choice screen. Whenever a user selected a search provider, that provider had to must pay Google the amount equivalent to the fourth-highest auction bid.

This "pay-to-play" mechanism has received numerous criticisms. Ostrovsky (2021) pointed out that the auction design proposed by Google potentially favored low-quality search engines that exact high-value data from users while pricing out alternative search providers that focus more on solving social, ethical, or ideological problems without generating high revenues. This view was also advocated strongly by Google's rivals. For instance, the not-for-profit search engine Ecosia indicated that the choice screen auction had essentially discriminated against non-profit search engines. DuckDuckGo, a search engine avoiding the "filter bubbleg of personalized search results, had also been a critic. The valuable privacy protection design by DuckDuckGo impeded its ability to place a high bid in the choice screen auction. Similar to most search engines, selling ads is the main channel for DuckDuckGo to monetize its services. Due to targeting users based solely on search box keywords without using user data, the search results provided by DuckDuckGo could be less relevant, less likely to be clicked on, and therefore less profitable.

In September 2021, a "free-to-play" choice screen replaced the original auction format. Within the new mechanism, participation in the choice screen is now completely free to all eligible search providers. In addition, the number of search engines appearing on the screen has been extended from four to twelve. Specifically, the five most popular eligible general search engines (including Google, all in random order) in each EEA state are always displayed at the top of the customer's scrollable list and are refreshed annually. The

[7] For a more extensive discussion of the features of internet search, see Decarolis et al. (2022).

[8] See https://www.google.com/search/howsearchworks/how-search-works/organizing-information/.

[9] See https://www.onely.com/blog/bing-vs-google-which-search-engine-indexes-more-content/.

[10] See https://platformobservatory.eu/app/uploads/2021/03/06CasestudyonMarketpowerandtransparencyinopendisplayadvertising.pdf.

[11] See https://ec.europa.eu/commission/presscorner/detail/en/IP_18_4581.

[12] See https://www.android.com/choicescreen/.

popularity of search providers is based on the market share estimates of StatCounter, a web traffic analysis website.[13] Below these most popular search providers, up to seven randomly chosen search engines are listed.

2.3. Digital markets act

Besides the Android choice screen, the EC acted to regulate the core platform services (CPS) that serve as gatekeepers, so that digital markets become fairer and more contestable.[14] To that end, the EC began drafting the Digital Markets Act (DMA) in December 2020 Gatekeepers refer to the platforms that have strong economic and intermediation positions. Those companies have continued to have significant impacts on the internal markets of multiple EU countries and link large user bases to large numbers of businesses.

To be formally defined as a gatekeeper in the DMA, a CPS provider has to meet three qualitative criteria listed in Article 3: (A) it has a significant impact on the internal market; (B) it provides a core platform service that is an important gateway for business users to reach end users; and (C) it enjoys an entrenched and durable position in its operations, or it is foreseeable that it will enjoy such a position in the near future. To quantitatively measure whether a CPS hits the qualitative criteria, the DMA further defines corresponding quantitative standards for a gatekeeper: (a) it has achieved an annual turnover equal to or above € 7.5 billion in each of the last three financial years, or its average market capitalization or its equivalent fair market value amounted to at least € 75 billion in the last financial year, and it provides the same core platform service in at least three Member States; (b) it provides a core platform service that in the last financial year had at least 45 million monthly active end users established or located in the Union and at least 10,000 yearly active business users established in the Union; (c) the thresholds in point (b) were met in each of the last three financial years. For any CPS provider that does not meet the quantitative standards, the EC can also designate it as a gatekeeper if the qualitative criteria are satisfied.

Given that Google's annual turnover surpasses € 200 billion[15] and it has a user base of over one billion individuals[16], it evidently satisfies the classification criteria and is deemed a gatekeeper within the realm of the online search market. This entails several obligations and restrictions within the new DMA regulation. As defined in Article 2, the DMA covers a wide range of market scopes, including online intermediation services, online search engines, operating systems, online social networking, video-sharing platform services, virtual assistants, number-independent interpersonal communication services, cloud computing services, web browsers, and online advertising services. Our paper mainly focuses on the sector of online search engines, which is regulated by the DMA mainly through three dimensions. One dimension targeted by the DMA is to level the playing field between the gatekeeper and its potential competitors. Several tools are geared toward this goal: for instance, Article 6.5 requests that the gatekeeper shall not treat more favorably, in ranking and related indexing and crawling, services or products offered by the gatekeeper itself than similar services or products of a third party. Moreover, the gatekeeper shall apply transparent, fair, and non-discriminatory conditions to such ranking. Since Google is dominant in almost every layer of the online advertising supply chain, it could easily foreclose its rivals while endowing its own services with more prominence. But within the new regulations of the DMA, such discriminatory conduct is no longer allowed and competing search engines should be exposed to more users in the online search market.

Similar to the Android choice screen, the DMA also attempts to make competition fairer by reducing the number of captive users locked in Google. New regulations in the DMA (Article 6.3) ensure users can easily change the default settings on an operating system. Gatekeepers are not allowed to prevent end users from uninstalling any software applications on their operating systems. Users of Android devices will therfore have the freedom to "choose" the default search engine on their devices and easily switch it whenever they want. In addition, multihoming is also encouraged in the DMA to diversify users' choices. According to Article 6.6, gatekeepers have the responsibility of ensuring users' ability to switch or multihome across different software applications and services. The increase in multihoming users is critical, as it helps competing search engines to attract advertisers and gain financial support. To illustrate, it is useful to compare two hypothetical extremes. When users are all singlehoming on Google, advertisers have no choice but to present on Google to reach potential purchasers. However, when users are all multihoming on all search engines, it becomes possible for advertisers to use other search engines to reach users. This, in turn, helps other search engines to better monetize their services.

The second dimension targeted by the DMA is enhancing the quality of Google's rivals. According to the new responsibilities listed in the DMA (Article 6.2), gatekeepers are now forbidden from using information from business users to compete against them. This is also vital as an intermediary and as an undertaking providing services competing with business users endow the company with great information advantages over the competition and may hurt other alternatives. Moreover, the DMA also directly helps competing search engines to improve their quality. According to the DMA (Article 6.7), the gatekeeper shall allow business users and alternative providers of services, free of charge, effective interoperability with the same operating system, hardware, or software features. The impact of the intervention can be illustrated by considering Google's existing self-favoring of its own search engine through the restriction of advertisers' value on rival search engines. As pointed out by the CMA, Google has been benefiting from the greater interoperability between its advertising expenditure optimizing tools (SA360) and Google Search.[17] For instance, data on bids from Google Search is fed back to SA360 and combined with conversion data in real-time, while data from Bing comes back only

[13] See https://statcounter.com/.

[14] See https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32022R1925&from=EN.

[15] See https://www.statista.com/statistics/266206/googles-annual-global-revenue/.

[16] See https://earthweb.com/how-many-people-use-google#::text=And%20in%202022%20that%20figure,people%20use%20Google%20every%20month.

[17] See https://assets.publishing.service.gov.uk/media/5fa557668fa8f5788db46efc/Final_report_Digital_ALT_TEXT.pdf.

periodically. Since advertisers normally have to use ancillary technology to appear on search engines, restricting the function of SA360 diminishes advertisers' motivation to join competing search engines. With the perfect interoperability as required by the DMA, all elements of a gatekeeper's hardware or software shall function the same with other companies. Therefore, advertisers using SA360 are expected to derive the same value when they post on Google or other search engines. This should increase the attractiveness of rival search engines on the advertiser side and is helpful for market competition.

The last dimension targeted by the DMA is data portability across search engines. The DMA (Article 6.11) requires gatekeepers to provide other search engines with access on fair, reasonable, and non-discriminatory terms to ranking, query, click and view data. Moreover, the DMA (Article 6.9) clarifies that gatekeepers also have the responsibility to provide end users and their authorized third parties with effective portability of data free of charge. Similar data-sharing terms also apply to advertisers and publishers in the online search market. In other words, competing search engines can potentially also employ Google's large, complete and high-quality click-and-query data set to train their algorithms. Thus, the quality difference induced by the enormous gulf in existing user numbers between Google and its rivals is expected to be lessened.

2.4. Digital services act

While the main focus of the DMA is to regulate gatekeepers in digital markets, the DSA concentrates on promoting a transparent and safe online environment.[18] The new rules in the DSA define the accountability of all digital service providers, reshaping the rights and responsibilities of digital service providers, online users, customers, and business users in various industries and multiple aspects.

As far as the online search market is concerned, the regulations in the DSA mainly translate into two aspects. First, digital platforms have the responsibility to provide users with essential and clear information about the advertisers they see and why they are targeted. As regulated in Article 26, all online platforms that display advertising on their online interfaces have *transparency obligations* to ensure the recipients of the service can identify several critical aspects of each advertisement. This includes the recognition of the content as an advertisement, the main criteria used to determine the recipients, and potential modification options. Beyond transparency obligations, Article 26 also effectively bans profiling-enabled personalized advertising based on special categories of data, and Article 28 bans advertising based on profiling in general when the recipient is a minor.

Second, the DSA further clarifies, in Article 39, the additional transparency and accountability duties of very large online platforms and very large online search engines. These platforms or search engines should have a monthly average of active service recipients in the European Union equal to or exceeding 45 million, or as designated by the EC. As shown in Articles 34–35, it is mandatory for very large online platforms to take measures for risk mitigation and engage in risk assessments, among others, of their recommendation and advertising systems. Moreover, very large online platforms and search engines that showcase advertisements on their interfaces must publicly provide a repository containing comprehensive information about the advertising, including, for instance, the advertisement content, its display period, and the total number of recipients of the service. Such information shall be available until one year after the advertisement was last displayed on the online interfaces of very large online platforms or very large online search engines. With the information, the Digital Service Coordinator, the EC, and vetted researchers are expected to better monitor and assess compliance of these very large online platforms.

Additional provisions of the DSA concentrate on the methods, systems, and techniques utilized by online platforms to influence consumers to purchase. As per Article 3 of the DSA, a "recommender system" is a partially or fully automated system utilized by an online platform to suggest specific information or prioritize that information on its online interface. This includes determining the relative order or prominence of the information presented as a result of a search by the service recipient or otherwise. Article 25 of the DSA specifically deals with "dark patterns", which refer to subtle methods integrated into the design or organization of interfaces to direct and nudge consumers toward making specific decisions. Additionally, Article 27 aims to enhance the transparency of recommendation systems that identify the type and prominence of commercial information presented to particular online platform users. Very large online platforms must also provide service recipients with the ability to modify information presentation parameters that are not based on online profiling but on objective criteria, such as price.

3. Conceptual model

We begin our analysis by presenting a simple theoretical framework that captures the online search market's prominent features. By analyzing users' choices across heterogeneous search engines, the model sheds light on how recent regulatory interventions are likely to affect the online search market. We first detail the model. Then, we characterize the subgame-perfect equilibria both in the short run and in the long run.

3.1. Model

The model focuses on the simple setting where there is a dominant firm g and a representative competing firm j. Each firm operates a search engine. Users are heterogeneous in sophistication, such that a proportion of $1-\alpha$ users are captive to the gatekeeper and the rest are shoppers considering both search engines. Captive users, who only consider the dominant firm, can arise for various reasons:

[18] See https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32022R2065&from=EN.

some users might become accustomed to specific search engine designs; some are concerned about losing historical data; some just use whatever search engine is pre-installed on their devices. Users all have a unit demand, that is, they choose at most one search engine. To simplify without loss of generality, we normalize user size to unity. We employ the conventional Hoteling model to study shoppers' choices between two search engines. As shown in Fig. 1, two firms are located at two ends, and shoppers are uniformly distributed on the normalized Hoteling line. Compared with the competing firm, the dominant firm has a larger existing market size.

To incorporate existing search market attributes, we assume the utility of using a search engine is increasing in its existing market size. This assumption is justified by the fact that search engines train their algorithms using users' click-and-query data. Hence, the higher the existing market share, the better quality the search engine is. This comparative advantage induced by network size difference can be reduced by data portability across search engines. By sharing data, a small search engine can also benefit from the larger datasets of the dominant search engine, thus its disadvantages caused by smaller network size are reduced. In line with the existing research (De Corniere and Taylor, 2014), we assume users have an aversion to search engines monetizing their data, which may stem from the disutility of viewing ads, potential misuse of personal information, or the threat of future price discrimination. Nevertheless, users might only possess partial awareness of the value extracted by search engines. Most search engines do not charge users a cash price. Rather, they amass and monetize user data and attention via advertising sales, about which users have limited knowledge. Consequently, users typically struggle to accurately gauge the exact value of their information to search engines.

If user i chooses product $k \in \{g, j\}$, she receives a utility of:

$$U(i,k) = V_k - \beta b_k - rd(i,k)$$

where V_k is the value of firm k's product, $\beta \geq 0$ is users' awareness of their value extracted by search engines, b_k is the value extracted from its users, r is the transportation cost parameter measuring users' disutility of not having one's ideal product, and $d(i,k)$ is the distance between user i's location and the firm. Specifically, $V_k = v_k + e(m_k + \theta m_{-k})$ such that v_k is the users' stand-alone utility for the product of firm k, e is the positive network effect across users, m_k is the firm's existing market share, m_{-k} is the existing market share of its competitor, $0 \leq \theta \leq 1$ measures the data portability across search engines.

To guarantee the concavity of search engines' profit, we make the following assumptions in our model.

Assumption 1. The transportation cost is sufficiently high such that $r > \alpha e(1-\theta)$

3.2. Equilibrium

Since the effects of different factors do not play out at the same time, we study the subgame-perfect equilibria in both the short run and the long run.

Short-Run Equilibrium In the short run, search engines' design strategies for how much value to extract from users are fixed. Within our model setup, the location of the shopper who is indifferent between two search engines is given by $U(i,j) = U(i,g)$ and $d(i,j) + d(i,g) = 1$. It follows that the demand for firm j equals:

$$q_j = \alpha\left(\frac{1}{2} + \frac{v_j - v_g - e(1-\theta)(m_g - m_j) + \beta(b_g - b_j)}{2r}\right) \tag{1}$$

where α is the number of shoppers considering the firm, and the second term is the probability of a shopper choosing search engine j. All other users select the search engine of firm g:

$$q_g = 1 - q_j = 1 - \alpha + \alpha\left(\frac{1}{2} + \frac{v_g - v_j - e(1-\theta)(m_j - m_g) + \beta(b_j - b_g)}{2r}\right) \tag{2}$$

For each search engine $k \in \{g, j\}$, its existing market shares m_k will gradually converge to the current demand q_k. Given $m_j = q_j$ and m_g

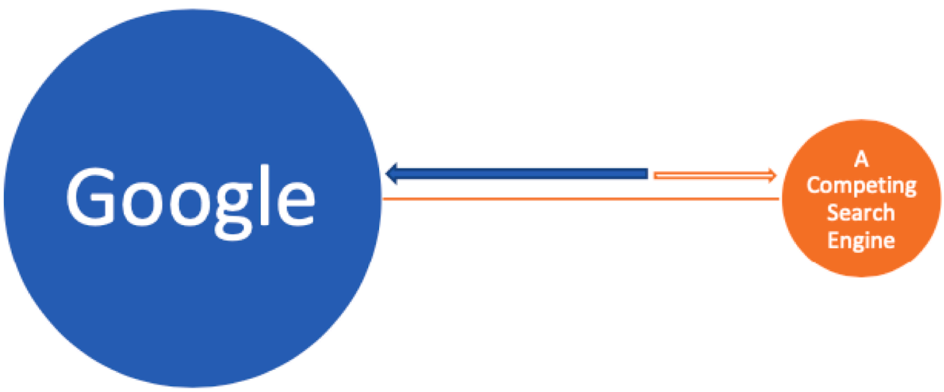

Fig. 1. Hotelling Line.

$= q_g$, the demands can be expressed as:

$$q_j = \frac{\alpha\left(\beta\left(b_g - b_j\right) + r - e(1-\theta) - v_g + v_j\right)}{2(r - \alpha e(1-\theta))}, \tag{3}$$

$$q_g = \frac{2r - \alpha\left(e + \beta b_g - \beta b_j + r - e\theta - v_g + v_j\right)}{2(r - \alpha e(1-\theta))}. \tag{4}$$

In the short run, the demand for each search engine q_k is decreasing in the value extracted from its users b_k. This is consistent with Ostrovsky (2021), who stated that it is normal for search engines to increase their popularity among users by reducing the intrusiveness of ads, increasing the protection of privacy, or even donating advertising proceeds to charity.

Long-Run Equilibrium Given sufficient time, search engines can adjust their strategy for how much value is extracted from users. Each search engine $k \in \{g, j\}$ maximizes its profit $\pi_k = b_k q_k$. The corresponding first-order conditions are:

$$\begin{cases} \dfrac{\partial \pi_j}{\partial b_j} = 0 \Leftrightarrow 2b_j = b_g + \dfrac{r - e(1-\theta) - v_g + v_j}{\beta}, \\ \dfrac{\partial \pi_g}{\partial b_g} = 0 \Leftrightarrow 2b_g = b_j + \dfrac{2r}{\alpha\beta} - \dfrac{e + r - e\theta - v_g + v_j}{\beta}. \end{cases}$$

Solving this system yields the search engines' optimal strategy for how much value to extract from users at the long-run subgame-perfect equilibrium:

$$b_g^* = \frac{4r - \alpha\left(r + 3e(1-\theta) - v_g + v_j\right)}{3\alpha\beta}, \tag{5}$$

$$b_j^* = \frac{2r + \alpha\left(r - 3e(1-\theta) - v_g + v_j\right)}{3\alpha\beta}. \tag{6}$$

Correspondingly, the resulting equilibrium demands are

$$q_j^* = \frac{2r + \alpha\left(r - 3e(1-\theta) - v_g + v_j\right)}{6(r - \alpha e(1-\theta))} \tag{7}$$

$$q_g^* = \frac{4r - \alpha\left(r + 3e(1-\theta) - v_g + v_j\right)}{6(r - \alpha e(1-\theta))} \tag{8}$$

Since a search engine's demand is increasing in its standalone value, there exist quality cutoffs such that both search engines derive positive demands when $\underline{v}_j^s < v_j < \overline{v}_j^s$ ($\underline{v}_j^l < v_j < \overline{v}_j^l$) in the short run (long run). The cutoffs highlight the fact that the quality of the competing search engine cannot be too low to derive positive demand. Otherwise, the market converges to the trivial one where the gatekeeper takes all the market share in the short run (long run), giving rise to a winner-takes-all phenomenon. However, the cutoffs also suggest that a competing search engine may rapidly accumulate market share from scratch, provided that the value of its service is sufficiently high. Specifically, the cutoffs are given by:

$$\begin{aligned} \underline{v}_j^s &= v_g + e + \beta\left(b_j - b_g\right) - r - e\theta \\ \overline{v}_j^s &= v_g + \beta\left(-b_g + b_j\right) + r + (-1 + 2\alpha)e(-1 + \theta) \\ \underline{v}_j^l &= v_g - r - \frac{2r}{\alpha} + 3e(1-\theta) \\ \overline{v}_j^l &= v_g + \left(5 - \frac{2}{\alpha}\right)r + 3(1 - 2\alpha)e(1-\theta) \end{aligned}$$

4. Intervention analysis

4.1. Android choice screen

We now proceed to study the Android choice screen implemented recently by the EC. By limiting Google's role as the default search engine on Android mobile devices, the choice screen ensures that more potential users consider Google's rivals.

In the online search market, users access search engines through various access points, such as browsers, search widgets, and voice assistants. A significant amount of users tend to use whatever is pre-installed on their search access points and they rarely make a switch in the future due to high switching costs, concerns of data loss, and possibly having no access to alternatives. Consequently, it becomes critical which search engine is initially associated with those access points, i.e., the "default" search engine.

Since Google operates the Android operating system, it can easily occupy the access points on Android mobile devices through various business techniques, such as providing subsidies to mobile manufacturers, tying its critical apps with its search engine, and bundling. In 2019, Google paid Apple around 1.2 billion for default positions in the UK alone. This figure was more than 17% of Googles total annual search revenues in the UK. According to a CMA report, Google search has taken the initial default position for 99% of the UK mobile device sector (by usage), with the remaining 1% of mobile devices unable to identify their default search engines.[19]

Investigating the impact of shoppers on market outcomes, we find that an increase in the number of shoppers α shifts up the demand for Google's rival as shown in expression (3). As a consequence, Google's market share diminishes while the market of its rival increases in the short run. In the long run, search engines adjust their designs in response to new regulations. In this context, an increase in the number of shoppers generates conflicting effects. Thus, the overall influence on the online search market becomes more complicated and uncertain.

On the one hand, having more shoppers indicates fewer users locked in Google. In other words, the competing search engine is in the consideration set of more users and should derive a higher demand. On the other hand, an increase in the number of shoppers also motivates Google to reduce the value it extracts from its users. With a smaller value to be extracted, more users are then attracted to Google instead of its competitor. As shown in expression (5) and expression (6), both gatekeeper g and competing search engine j reduce their value extracted from users when the number of shoppers α increases. With fewer captive users, the market becomes more competitive and search engines change their designs correspondingly. Calculating the difference between user values extracted by two search engines at the equilibrium $b_g - b_j = 2(r - \alpha r + \alpha(v_g - v_j))/3\alpha\beta$, we find that the relative value extracted by Google over its competitor decreases in the number of shoppers.

To examine the overall impact, we calculate the derivatives of both demands concerning the number of shoppers:

$$\frac{\partial q_j^*}{\partial \alpha} = \frac{r\big(r - e(1-\theta) - v_g + v_j\big)}{6(r - \alpha e(1-\theta))^2}, \tag{9}$$

$$\frac{\partial q_g^*}{\partial \alpha} = -\frac{\partial q_j^*}{\partial \alpha} \tag{10}$$

Our results indicate that the overall impact of shoppers depends on the quality of the search engines. Precisely, there exists a quality cutoff $\overline{v_j} = v_g + e(1-\theta) - r$ such that the demand for Google's rival increases in the number of shoppers when its quality is sufficiently high $v_j > \overline{v_j}$, and decreases otherwise. Moreover, we also find that $\partial q_j/\partial\alpha$ is increasing in v_j, meaning that a competing search engine with high quality is more likely to benefit from being exposed to users. This conclusion is consistent with the recent analysis by Decarolis et al. (2022), who quantitatively examine the Android choice screen and compare it with related interventions in Russia and Turkey. The paper shows the causal impact of public intervention amounts to less than 2 percentage points in the EEA, 7 percentage points in Russia, and 12 percentage points in Turkey. Comparing the three remedies, the paper concludes that interventions involving consumer choices via a choice screen can have little impact on online search market competition unless there is a qualified challenger who can compete with Google on quality or a rival who has the means and motivation to replace Google by investing in the local market.

Extending the research of Decarolis et al. (2022) that focuses on the time frame before January 2022, we employ the market share data on StatCounter and compare the mean of Google's market share between January 2016 and February 2023 across EEA countries with that across other countries in Europe in Fig. 2. We remove Russia and Turkey from the control group since they have implemented similar interventions for Google's illegal practices in Android devices.

From a visual inspection of the figure, the decline of Google's market share in the EEA seems to be more pronounced than in the control group. However, the difference is extremely small. According to StatCounter's estimates, Google accounted for 98.58% of the mobile market in EEA states in March 2020, when the choice screen was first implemented. In August 2022, almost two years after the introduction of the choice screen, Google's mobile market share in the EEA is still 97.66%. Comparing the market shares, we see that the reduction in Google's market share is even smaller than 1 percentage point.

4.2. Digital markets act

The Android choice screen underscores that increasing access to users is not enough and that viable challengers to the gatekeeper must be fostered if the market is to be substantially changed. Similar to the Android choice screen, several regulations in the DMA also aim at increasing the number of shoppers in the online search market. However, other new legislations and regulations in the DMA are also simultaneously proposed to enhance the quality of Google's rivals and to promote data portability among search engines. In this section, we analyze how these regulations affect the market outcomes in the online search market.

Quality Enhancement According to the previous analysis of the Android choice screen, the competitiveness of the gatekeeper's rival plays a paramount role in determining the impact of having more shoppers in the online search market. Without the presence of a sufficiently qualified search engine that is capable of challenging Google, users will continue to stick with Google even when they are reminded about other alternatives. Following the new responsibility documented in the DMA, the gatekeeper must offer other firms, free of charge, effective interoperability with the same hardware and software features as are available to itself. In other words, the gatekeeper can no longer practice self-preferencing by endowing its own product with additional or better services. Consequently, users' relative standalone value in using other search engines should be increased.

[19] See https://assets.publishing.service.gov.uk/media/5fa557668fa8f5788db46efc/Final_report_Digital_ALT_TEXT.pdf.

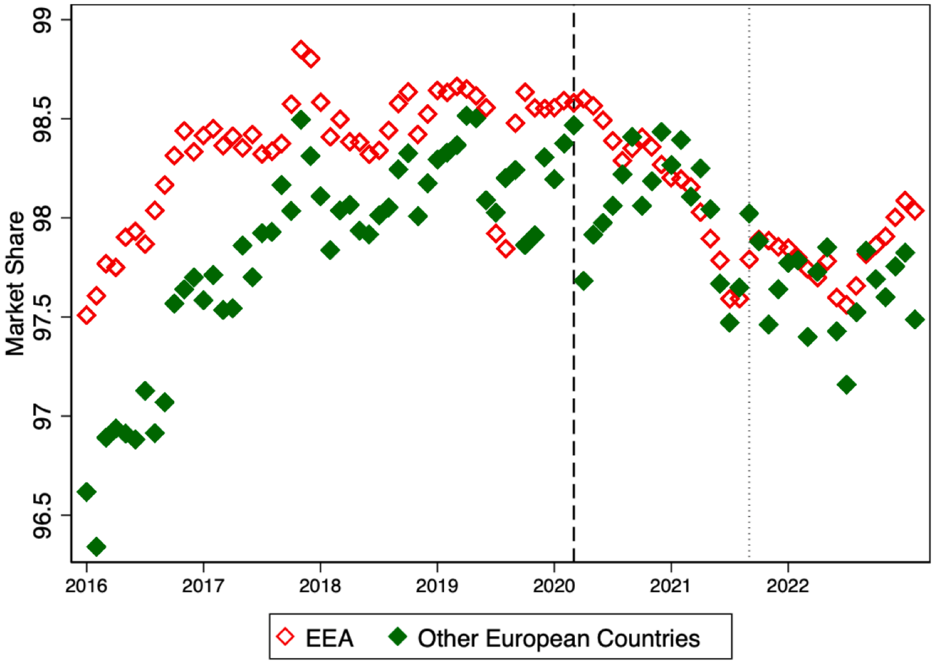

Fig. 2. Google Mobile Market Share. *Notes:* the vertical lines correspond to the introduction of the pay-to-play and free-to-play choice screens, respectively.

An increase in the service quality should reinforce the impact of other interventions, such as the Android choice screen. Moreover, reducing the difference in search quality $v_g - v_j$ between Google and its competitor also directly affects the market shares. As displayed in the demand functions (3) and (4), an increase in the competitor's quality of service will effectively diminish Google's market share and direct more users to the competitor, both in the short run and in the long run. Checking search engines' strategy for how much user value to extract in the long run, we also find that an increase in the quality of competing search engines motivates Google to reduce the value it extracts from users. Thus, in the long run, even users who remain with Google should also benefit from the smaller value extracted by the search engine.

Data Portability

Search engines normally rely on click-and-query data to train their algorithms and test potential search adjustments. Therefore, how much data a search engine has access to plays an essential role in determining its search quality. Compared with its competitors, Google has unique advantages in accessing data. Its dominant market share has guaranteed that Google has much more first-hand click-and-query data than its competitors. Without a similar market share, it is extremely hard for a competing search engine to conquer these barriers, and thus new regulations are urgently needed.

Regulations in the DMA have been facilitating data portability among the gatekeeper and smaller search engines, so the gatekeeper's comparative advantages from the dominant network size are reduced. This can be easily illustrated if we consider the extreme case where the existing market share remains fixed after the intervention. Since Google's existing market share is substantially higher than other search engines, an increase in data portability θ is equivalent to expanding the existing user size of the competing search engine. Therefore, the network effect disparity between Google and its competitors is diminished, along with the difference in market share.

Once m_k converges with q_k, the impact of data portability is determined jointly by search engines' qualities and user value extraction. To better comprehend the underlying mechanisms through which data portability affects the online search market, we revisit our conceptual model.

$$\frac{\partial q_j^*}{\partial \theta} = \frac{\alpha e\left(r - \alpha\left(\beta\left(b_g - b_k\right) - r + v_g - v_j\right)\right)}{2\left(r - \alpha e(1-\theta)\right)^2}, \tag{11}$$

$$\frac{\partial q_g^*}{\partial \theta} = -\frac{\partial q_j^*}{\partial \theta} \tag{12}$$

We find that in the short run, higher θ should help competing search engines gain more market share unless $v_j > v_g + \beta(b_j - b_g) + r(1/\alpha - 1)$. With $\theta > 0$, a search engine benefits not only from its users, but also partly from the users of other search engines. As a consequence, the relative user size between two search engines is the essential determinant of who benefits more from data sharing with others. Search engines with smaller user sizes should gain more from enhanced data portability with larger search engines.

In the long run, search engines can adjust how much value is extracted from users. Calculating the derivative of the long-run demand, we find:

$$\frac{\partial q_j^*}{\partial \theta} = \frac{\alpha e\left((1-\alpha)t + \alpha\left(v_g - v_k\right)\right)}{6(r - \alpha e(1-\theta))^2}, \quad (13)$$

$$\frac{\partial q_g^*}{\partial \theta} = -\frac{\partial q_j^*}{\partial \theta} \quad (14)$$

The result indicates that data portability will benefit the competing search engine most of the time unless its quality is considerably better than that of Google: $v_j > v_g + (1-\alpha)r/\alpha$. Based on the preceding overview of the current search market, we doubt whether there exists a competing search engine that exceeds the threshold. Thus, an improvement in data portability is expected to help restore competition in the online search market.

Besides the direct impact imposed on demand, data portability also indirectly influences the search market by enhancing the impacts of other regulations in the DMA. Recall that there exists a quality cutoff $\underline{v}_j^l$, such that only search engines whose quality is higher than this threshold will attract a positive number of users to their services. An increase in θ across search engines will effectively reduce this quality threshold. This means more search engines are sufficiently qualified to "actively" compete against Google and overall competition in the online search market should be facilitated. Furthermore, an increase in θ also reduces the quality cutoff $\overline{v_j}$, beyond which search engines gain market share from regulations increasing the number of shoppers. This highlights the fact that the interventions in the DMA are not mutually independent. Indeed, the impact of the DMA's interventions focusing on one dimension is, to some extent, determined by its interventions in other dimensions.

4.3. Digital services act

A primary aspect of the DSA involves ensuring users are frequently and clearly informed about how search engines monetize their data through advertising. This feature within the model corresponds to an increase in the awareness about the value extracted by search engines, β. Considering the short-term demand shown in (4), the derivative of the demand for Google's competitors can be expressed as

$$\frac{\partial q_j}{\partial \beta} = \frac{\alpha\left(b_g - b_j\right)}{2(r - \alpha e(1-\theta)} \quad (15)$$

Once users become more aware of whether and what information is collected by search engines, they start prioritizing privacy when selecting a search engine. This shift leads users towards search engines offering superior privacy protection. In essence, the DSA is anticipated to enhance demand for search engines that can compete with Google by providing better privacy safeguards.

In Table 1, we present the privacy measurements of popular search engines, as determined by the Ranking Digital Rights (RDR) methodology.[20] These measurements are based on the privacy policies published by each respective search engine in July 2020 and can be divided into four distinct categories. The first category (accessibility and clarity) evaluates the accessibility and clarity of their privacy policies, focusing on the ease with which they can be found and their comprehensibility, as well as the provision of notices and documentation when changes occur. The second category (user information) examines the user information score, which assesses how companies handle user data, including collection, sharing, purpose, retention, and users' control of and access to their information. The third category (government demands) encompasses procedures and data disclosure in response to requests for user information from government and third-party entities. Lastly, the fourth category (security) analyzes security oversight, vulnerability management, data breach handling, encryption of user communication, account security, and user education regarding potential risks. The better a search engine protects its users' privacy, the higher its quality score. Although Google is currently the most popular search engine, its protection of user privacy is not the best. When users become more aware of the actual value that Google extracts from their data, we expect more will switch to search engines with better privacy protection, like DuckDuckgo, Seznam, and Qwant.

In the long run, greater user awareness of search engines monetizing their information will have more profound and vital impacts on the online search market. This is because search engines have time to adjust their privacy setting in response to users' tastes in the long run. Recall the equilibrium design in expressions (5) and (6), thus the user value extracted by search engines is decreasing in the awareness β. When users place more weight on privacy protection in their choice of search engine, there is a stronger motivation for search engines to reduce the value collected from users and to provide them with better privacy protection. Consequently, if the DSA can considerably elevate users' awareness of the value harnessed by search engines, it is expected that search engines will prioritize user privacy more, resulting in improved information security.

5. Extensions

5.1. Multihoming users

Until now we have assumed that all users use at most one search engine (i.e., singlehoming), but in real markets, users may have the

[20] See https://rankingdigitalrights.org/bts22/.

Table 1
Search Engine Privacy Score.

	DuckDuckGo	Yandex	Qwant	Bing	Google	Ecosia	Seznam
Accessibility and clarity score	100.0	75.0	93.8	81.3	75.0	50.0	70.8
User information score	90.36	34.29	85.36	41.43	55.95	77.14	87.14
Government demands score	33.33	5.56	8.59	67.16	67.17	0.00	39.39
Security score	35.00	56.73	50.00	50.00	53.33	20.00	63.33
Total score	61.53	38.35	58.93	50.22	56.10	41.11	65.92

option to use multiple search engines simultaneously (i.e., multihoming). To consider this possibility, we assume in this section that all shoppers wish to deal with both search engines. In this context, the decision for a user is not merely an "either/or" choice between two search engines, but an independent choice regarding the usage of each search engine. In such a multihoming scenario, data portability for multihoming users may only provide repeated data and offer little additional value to search engines. To simplify the analysis, we concentrate on the setting where $\theta = 0$ and retain all other configurations as in the benchmark.

A portion of $1 - \alpha$ users remains captive to the gatekeeper and the rest of the users are multihoming shoppers considering both search engines. In this multihoming scenario, a shopper will use a search engine as long as it provides positive utility. Therefore, the position of the indifferent shopper on whether to use search engine $k \in \{g, j\}$ is given by $U(i, k) = 0$. Following the same steps as the benchmark, we derive the demands for two search engines as

$$q_j = \frac{\alpha(v_j - \beta b_j)}{r - \alpha e},$$
$$q_g = \frac{r + \alpha(v_g - \beta b_g - r)}{r - \alpha e}.$$

Each search engine $k \in \{g, j\}$ maximizes its profit $\pi_k = b_k q_k$ and achieves the corresponding long-term subgame-perfect equilibrium equal to:

$$b_g^* = \frac{r - \alpha r + \alpha v_g}{2\alpha\beta},$$
$$b_j^* = \frac{v_j}{2\beta}.$$

Plugging in the equilibrium user value obtained by search engines, we write the demands as:

$$q_j^* = \frac{\alpha v_j}{2(r - \alpha e)} \tag{16}$$

$$q_g^* = \frac{r - \alpha r + \alpha v_g}{2(r - \alpha e)} \tag{17}$$

$$m_{jg}^* = \max\left\{0, \frac{\alpha(2e - r + v_g + v_k) - r}{2(r - \alpha e)}\right\} \tag{18}$$

where m_{jg} is the multihoming users who use both search engines at the same time.

To examine the impact of interventions, we first examine how the fraction of multihoming users is affected by the number of shoppers. By taking the derivative, we get:

$$\frac{\partial m_{jg}^*}{\partial \alpha} = \frac{r(e - r + v_g + v_j)}{2(-\alpha e + r)^2}, \tag{19}$$

Given a positive number of multihoming users, the impact of shoppers depends on the similarity between search engines. When the transportation cost is not too high $r < e + v_g + v_j$, the number of multihoming users increases in the number of shoppers α, and vice versa. Since $m_{jg} = q_j + q_g - 1$, it is useful to break down the overall effect into two distinct impacts on each search engine. With simple calculations, we can easily show that having more shoppers always increases the demand for Google's rival in the multihoming case. However, its impact on Google's market share is uncertain. On the one hand, the reduction in captive users diminishes Google's market share. On the other hand, an increase in the number of shoppers motivates Google to reduce the value extracted from users and thus increase its demand. When the transportation cost r is low, the positive impact becomes dominant. Therefore, the demand for Google and thus the number of multihoming users are increasing in the number of shoppers.

We also find that the portion of multihoming users is (weakly) increasing in the quality of both search engines v_g and v_j. When there is an improvement in search engine quality, more users are encouraged to use an additional search engine. Nevertheless, users' awareness of how much value is extracted by search engines has no impact on the multihoming demand. Given that multiple regulations within the DMA target increasing the number of shoppers and search engine quality simultaneously, our projection suggests that the number of singlehoming users transitioning to multihoming will rise, reducing the gatekeeper's service exclusivity.

5.2. User value

Besides multihoming, another interesting extension would be to examine how regulations limiting gatekeeper's data extraction affect the online search market. In the benchmark, we assume that the network effect e is independent of the user value extracted by search engines b. Nevertheless, real markets suggest a positive correlation between user value and network effects. When a search engine collects more data from users, it is expected to increase targeting accuracy and extract more value from users. Meanwhile, more available data can also improve user interactions and network effects. To incorporate this effect, we now assume the network effect is positively affected by the user value extracted by search engines, i.e. $\frac{\partial e}{\partial b_k} > 0$ with $k \in \{g, j\}$.

When interventions place a binding ceiling on the value extraction from users by the gatekeeper, there can be conflicting impacts in this scenario. This can be illustrated by the derivative of Eq. (4) with respect to b_g

$$\frac{\partial q_j}{\partial b_g} = \frac{\alpha\beta}{2(r - \alpha e(1-\theta))} + \frac{\alpha(1-\theta)\left(-r + \alpha\left(\beta\left(b_g - b_j\right) + r - v_g + v_k\right)\right)}{2(r - \alpha e(1-\theta))^2}\frac{\partial e}{\partial b_g} \tag{20}$$

$$\frac{\partial q_j}{\partial b_g} = 1 - \frac{\partial q_j}{\partial b_g} \tag{21}$$

As shown in the equation, a reduction in b_g lowers users' cost of using Google and directly decreases users' demand for its rivals. However, its indirect impact through network effects is uncertain. When network effects are diminished due to lower b_g, search engines with larger user bases experience more pronounced negative repercussions. Consequently, when the rival search engine's quality is not exceedingly high, a lower b_g undermines Google's network advantages, drawing more users towards the competing search engine. Therefore, the overall impact of data extraction is jointly determined by search engine qualities and the dependence of network effects on data.

6. Conclusion

With over 90% market share in most countries in Europe, Google plays a dominant role in the online search market. The gigantic mass of users on Google has endowed the firm with significant competitive advantages via network effects and economies of scale in costs. Moreover, Google presents itself in almost every layer of the advertising industry, which further provides the company additional comparative advantages through information collection, product tying, and self-preferencing. These existing market features have generated entry barriers and comparative disadvantages that other firms may struggle to conquer. Thus, regulators in Europe have been reacting rapidly. In this study, we consider three interventions. In 2020, the EC limited Google's position as the default search engine on all Android mobile devices in the EEA. Google was then required to provide users with a choice screen in Android devices' initial setup, through which users can choose their preferred default search engine instead of having Google pre-installed automatically. During the same period, the EC also started drafting the DMA and DSA, through which it acted to regulate the core platform services (CPS) serving as gatekeepers and to promote a transparent and safe online environment.

In this study, we offer the first systematic analysis of the likely effects of these regulations. We provide a simple conceptual model that incorporates the prominent features in the online market. By integrating the regulations within the model, we demonstrate the underlying mechanisms and potential determinants of the impacts of the regulations on the online search market. We begin our analysis by studying the Android choice screen recently introduced in the EEA. We find the choice screen can effectively restore competition only if there exists a competing search engine with sufficiently high quality.

We then extend the analysis to the upcoming DMA and DSA. We categorize regulations in the DMA involving the online search market into three dimensions: increasing potential users considering Google's rivals, enhancing their quality, and improving data portability across search engines. Analyzing the impact of regulations, we show that these three dimensions mutually support and reinforce each other. Precisely, both data portability and quality enhancement assist more search engines to be sufficiently qualified to challenge Google and increase demand from additional users considering their services. Considering that the DMA targets all these three dimensions simultaneously, the impact of the DMA is expected to be stronger than the choice screen if appropriately designed. Within the new rules of the DSA, which aims at promoting a transparent and safe online environment, users should have a greater awareness of search engines collecting and monetizing their information. In the short run, the regulations in the DSA direct users to search engines with better privacy protections. The change in users' tastes can also generate stronger motivations for search engines to improve internet security in the long run, so users enjoy overall better privacy protection.

Our paper leaves several open questions for future research. First, as both the DMA and the DSA move into the implementation phase, quantitative investigations of their impacts on the online search market will become feasible. Additionally, there are other related regulations that are being advanced concurrently. These include the Platform to Business Regulation, which enforces detailed transparency obligations governing commercial content ranking on platforms; the Proposal for e-Privacy Regulation, which emphasizes data protection in the electronic communications industry; and the Proposal for an Artificial Intelligence Act, which addresses the requisite requirements necessary for managing the risks and concerns associated with AI. As illustrated in our research, the impacts of regulations are interdependent. Thus, it would be interesting to study how those regulations interact with the three regulations we focus on in this paper. Second, although some of the regulatory interventions discussed in this study will likely succeed in curtailing Google's market share, this outcome does not necessarily imply increased social welfare. A world without a gatekeeper in internet search might cause harm to both users and advertisers. For instance, doing business on the Google Ads platform currently entails a series of conditions defined by Google and, in case of non-compliance, Google can refuse ads, block sites, or suspend the advertisers accounts. In particular, these rules cover four broad areas: (i) prohibited content provisions forbid the sale of counterfeit goods, dangerous products or services, and the enabling of dishonest behavior or inappropriate content; (ii) prohibited practices rules prevent abuse of the ad network, data collection and use; (iii) restricted content and features rules prevent sexual content, alcohol, copyright infringements, gambling and games, political content, and the like; (iv) editorial and technical rules impose high professional standards and compliance with some formal elements. This sort of "private policing" of the web creates value for a significant share of users on both sides of the search platform. Thus, once the new regulations are in place, careful analysis will be needed to ensure that they foster the social value of search.

Our paper does not take operating costs into consideration. In the online search market, the cost of serving additional users is expected to follow economies of scale. Thus, in addition to the network advantages discussed in the paper, Google's large existing user size can endow the search engine with much lower marginal costs for serving each user. This partly explains why some search engines do not index as much data as Google and they might have to extract higher value from users to cover the costs. Lastly, we must note that features of the online search market discussed in this study may not apply to other areas of the digital economy. For instance, the positive within-group network effect in the online search market is not a feature of all online platforms. Indeed, users of digital marketplaces may suffer from competitive effects with each other and this might generate negative within-group network effects instead. Therefore, additional studies are required to investigate the broader impacts of the new digital market regulations on the functioning of the digital economy.

Credit Author Statement

All the authors contributed equally to the paper.

Data availability

The data used for the research described in the article is public available on https://statcounter.com/.

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