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Relevant Markets and Market Power of Mobile Apps

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Relevant Markets and Market Power of Mobile Apps*

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Abstract

In this article, we discuss methods for defining relevant markets and evaluating the market power of mobile apps and mobile Operating Systems (OSs), which are necessary for evaluating the market power of digital platforms such as Apple and Google in the mobile app economy. To this end, we first provide an overview of the mobile app economy. Second, we summarize antitrust cases involving mobile apps and mobile OSs and discuss issues related to the market definition for mobile apps and mobile OSs. Third, building on the theoretical and empirical literature, we discuss the behaviors of the leading players in the mobile app economy, such as mobile app users, advertisers, and developers. Lastly, we propose empirical methods for defining relevant markets and evaluating the market power of mobile apps and mobile OSs using data on the demand of consumers and advertisers for mobile apps.

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1 Introduction

This study discusses the methods for defining relevant markets and evaluating the market power of mobile apps and mobile Operating Systems (OSs), which are required to review the market power of digital platforms such as Apple and Google in the mobile app economy.

We refer to the mobile app economy as all markets related to the use of mobile devices (e.g., smartphones and tablets) and mobile apps that run on mobile devices, which play an important role in modern economic activities. According to a survey conducted by Ministry of Internal Affairs and Communications (2021), the penetration rate of mobile devices for internet access is 68.3% for smartphones and 24.1% for tablets. The fact that the penetration rate of mobile devices exceeds that of Personal Computers (PCs; 50.4%) implies that mobile devices have become the main devices for Internet access. Regarding mobile app developers, another important player in the mobile app economy, AppAnnie (2021) documented that the global mobile app economy in 2020 had more than 100,000 developer accounts registered with app stores. Among these registered accounts, 97% of them are small-scale accounts with annual sales less than $100,000. [1]

Competition authorities focus on the conduct of digital platforms such as Apple and Google, which play a core role in the mobile app economy. These digital platforms provide mobile OSs, such as iOS and Android, and design rules in various areas of the mobile app economy using potentially anticompetitive conducts, such as the specification of the terms of services and vertical integration. In addition to digital platforms that provide mobile OS, some large-scale mobile app developers such as Meta (which owns Facebook) and Z Holdings (which owns Yahoo! Japan and LINE) also play key roles in the app economy. Competition authorities sometimes regard mergers involving such developers as problematic because they can have anticompetitive effects.

In the current competition policy practice, when assessing the anti-competitiveness of a conduct of digital platforms and large-scale app developers, the antitrust authority will first have to define the relevant market and evaluate the market power of mobile apps and mobile OSs. This is because the anti-competitiveness of the digital platform's conduct needs to be assessed by considering the responses of consumers and mobile app developers

[1] The number of registered developer accounts is not necessarily the number of mobile app developing firms and individuals and does not necessarily represent the number of decision-making firms in an economic model. In some cases, multiple firms may use one account to register the mobile apps they have developed, and in other cases, one firm may hold and manage multiple developer accounts. An example of the former is the developer account of Nintendo that distributes Super Mario Run (https://supermariorun.com/ja/, accessed on April 15, 2022), developed by Nintendo and Dragalia Lost (https://dragalialost.com/jp/, accessed on April 15, 2022), developed by Cygames. Cygames holds its own developer account and publishes other apps, such as Uma Musume Pretty Derby. (https://umamusume.jp/, accessed on April 15, 2022). An example of the latter is the Match Group, which holds developer accounts for Meetic, OkCupid, Tinder Inc., and others. (https://mtch.com/jp/ourcompany, accessed on April 15, 2022).

who make transactions through mobile OSs, and the anti-competitiveness of the mobile app developer's conduct needs to be assessed by taking into account the responses of consumers and advertisers. Therefore, an economic analysis tailored to the mobile app economy is required.

Specifically, we need to answer the following questions: at what margin from the purchase of a mobile device to the use of a mobile app, does the substitution of mobile OSs and mobile apps occur? Will competition occur with goods in adjacent markets (e.g., PCs, game consoles) outside the mobile app economy? How do we consider the two-sidedness of mobile apps for consumers and advertisers? How do we consider multiple business models that rely on advertising revenue, including free apps? How do we consider the two-sidedness of digital platforms for consumers and developers?

In this study, we discuss the methods for defining relevant markets and evaluating market power in the mobile app economy to conduct an economic analysis that starts from the assessment of the market power of mobile apps. Section 2 summarizes the mobile app economy and clarifies the issues in performing market definition and market power assessment in the mobile app economy by discussing competition law cases in which market power assessment for digital platform business operators or large-scale app developers was an issue.

Based on the discussion in Section 2, Section 3 provides theoretical considerations on the methods of market definition and market power assessment in the mobile app economy by referring to the literature on platform economy. Finally, Section 4 discusses methods for empirically defining the market and market power assessment on digital platforms and mobile app developers.

This study does not discuss the economic analysis of the anti-competitiveness of large-scale app developers' and digital platforms' conduct that would follow the definition and market power assessment of the mobile app and mobile OS market.

2 Institutional Background

This section briefly describes the mobile app economy. In this study, the term "mobile app economy" means the entire market that includes all products, services, and players that are necessary for mobile app developers to develop mobile apps and for consumers to use mobile apps.

First, we define the main components of the mobile app economy. According to Competition and Markets Authority (2021), the mobile app economy comprises three major product groups. The first product group is mobile devices. In this study, mobile devices are devices such as smartphones and tablets with Internet access. The second product group is mobile OSs. In this study, mobile OS refers to the software required to use mobile apps on a mobile device. The third product group is mobile apps. In this study, a mobile app refers to software that performs certain functions on a device.

In addition to these three major product groups, additional services exist in the mobile app economy. One is mobile app distribution services, which allow consumers to install apps on their devices. The another is mobile app monetization services that provide mobile app developers with means of monetization.

Markets adjacent to the mobile app economy may compete with product groups in the mobile app economy. Adjacent markets of mobile devices include devices such as PCs and game consoles; adjacent markets of mobile OSs include OSs such as Windows, macOS, and OS for a game console; and adjacent markets of mobile apps include apps such as web apps and game software. Mobile app distribution services and mobile app monetization services also have adjacent markets, such as game distribution platforms and online billing services.

2.1 Components of mobile app economy

This subsection describes the goods and producers for each component of the mobile app economy.

Mobile devices The mobile devices analyzed in this study are smartphones and tablets. In this study, we regard portable laptop PCs and game consoles, as well as desktop PCs and game consoles, as products in adjacent markets that potentially compete with mobile devices.

According to Gartner's survey on the number of smartphones sold in the world in 2020, Samsung had an 18.8% share, followed by Apple, the producer of the iPhone, with 14.8%, followed by Chinese smartphone producers, Huawei with 13.5%, Xiaomi with 10.8%, OPPO with 8.3%, and other producers had a 33.7% share. [2]

In the Japanese market, Apple and Japanese manufacturers have a large share.[3] For example, according to an IDC survey on the number of smartphones sold in Japan in 2020, Apple had a 47.3% share, followed by Sharp, Fujitsu, Samsung, and Kyocera with a combined share of 36.6%. Although not ranked high in share, Google has also produced pixel-branded smartphones.[4]

Mobile OSs The major producers of mobile OSs in the mobile app economy are Apple and Google, the producers of iOS and Android, respectively.

Apple does not license iOS to other companies and uses iOS exclusively for the

[2] https://www.gartner.com/en/newsroom/press-releases/2021-02-22-4q20-smartphone-market-share-release, accessed on April 9, 2022.

[3] https://www.idc.com/getdoc.jsp?containerId=prJPJ47477421, accessed on 28 March 2022.

[4] https://store.google.com/jp/category/phones?hl=ja, accessed on April 15, 2022.

iPhone.[5] In addition, Apple does not allow other mobile OSs to be installed on the iPhone. [6]

Google develops a part of Android through the Android Open Source Project (AOSP).[7] Android is a combination of AOSP and Google Mobile Services (GMS) developed by Google. Because AOSP is licensed with the Apache 2.0 license, any producer can produce a mobile OS containing AOSP as a part of it. [8] GMS is a software bundle for that Google has individual property rights. Therefore, the use of Android, a combination of AOSP and GMS, requires a license from Google.

A mobile OS created by combining AOSP with a group of software created by firms other than Google is called an Android fork. For example, Amazon's Fire OS is an Android fork in which AOSP is combined with a group of apps Amazon developed (e.g., Amazon Appstore) and is used as a mobile OS for mobile devices made by Amazon.[9]

Mobile apps A mobile app is a native app that can be installed on a mobile device. Another form of an app is a web app which is used on a web browser. We regard web apps as apps in an adjacent market that potentially compete with mobile apps.

Mobile app developers produce mobile apps. Most mobile app developers are firms independent of the producers of mobile OSs, and their scales vary significantly. Regarding small-scale mobile app developers, as stated in Section 1, more than 100,000 accounts of small-scale developers with annual sales of less than $100,000 have been registered, and these small-scale developers account for 97% of mobile app developers.

Among large-scale mobile app developers, those who provide mobile apps that are ranked high in the number of downloads and usage include Meta (the producer of multiple social apps such as Facebook, WhatsApp, and Instagram) and Match Group (the producer of multiple matching apps such as Tinder and OkCupid). Among mobile app developers in Japan, LINE Corporation (the producer of the LINE app) is ranked high in the Japanese market.

Some producers of mobile OSs also develop mobile apps. For example, Apple provides the Apple Music app for iOS and Android. [10] Similarly, Google provides a Gmail app for both iOS and Android as a mobile app. Google also provides web apps that can

[5] Apple produces OSs named differently for each device type, such as iPadOS and tvOS, in addition to iOS. The iOS was usable on both the iPhone and iPad up to version 12, but different names have been used since the iOS13. However, they are not distinguished in terms of service or Application Programming Interface (API) documents. https://developer.apple.com/documentation/ios-ipados-release-notes, accessed on 7 April 2022.

[6] Project Sandcastle can run Android on iPhones, but some hardware functions remain unusable. https://projectsandcastle.org/, accessed on April 7, 2022.

[7] https://source.android.com/license, accessed on April 7, 2022.

[8] The Apache 2.0 license is a software license provided by the Apache Software Foundation (ASF), which allows developers to modify the software provided under the Apache 2.0 license and commercially distribute it. https://www.apache.org/licenses/LICENSE-2.0, accessed on April 7, 2022.

[9] https://developer.amazon.com/ja/docs/fire-tv/fire-os-overview.html, accessed on April 7, 2022.

[10] https://www.apple.com/apple-music/ , accessed on April 9, 2022.

be accessed through a browser.[11] In addition, Apple and Google provide various mobile apps.

Mobile app distribution services Mobile app distribution services refer to services that enable app developers to distribute mobile apps.[12]

Apple's App Store and Google Play Store are the major mobile app distribution services for iOS and Android. [13] The Competition and Markets Authority (2021) stated that the App Store is the only mobile app distribution service authorized for the iPhone.[14] Google's Play Store app is pre-installed on mobile devices that use Android as mobile OS. In some cases, Android device manufacturers pre-install its mobile app stores. For example, the Competition and Markets Authority (2021) stated that Samsung was shipping mobile devices that pre-installed the Galaxy Store. In addition, consumers with Android devices can download mobile apps from websites. [15]

Mobile app stores provide ancillary services to mobile app developers. For example, Apple Search Ads[16] and Google App campaigns[17] are available as services for advertising mobile apps.

Mobile app monetization services Mobile app monetization services allow mobile app developers to earn profits through their mobile apps. These services include billing and distribution of advertisement services. Specifically, mobile app producers can charge consumers using billing services or sell advertisement spaces placed on their mobile apps to advertisers using ad distribution services.

A mobile app developer may charge a consumer when the consumer downloads the app (pay-per-download) or charges inside the app depending on the way the consumer

[11] https://support.google.com/youtube/answer/3227660, accessed on April 9, 2022.

[12] The means to distribute mobile apps other than mobile app distribution services including the distribution through a website or repository and attaching them to emails. Google suggests app markets ("mobile app stores" in this study), attaching to emails, and websites as means to distribute mobile apps for Android. https://developer.android.com/distribute/marketing-tools/alternative-distribution, accessed on April 15, 2022.

[13] The market share of mobile app stores in Japan is unknown. The Competition and Markets Authority (2021) stated that the share of mobile app distribution services for mobile devices with iOS, Android, HMS, or Fire OS in the UK in 2020 was 40–50% for Apple App Store, 50–60% for the Google Play Store and 0–5% for installation from other mobile app stores.

[14] The process of users installing an app by bypassing the restrictions posed by the device producer is called jailbreak. In December 2020, the developer of Cydia, which provided a method to install its mobile apps bypassing software restrictions by Apple, and a mobile app store, which provided mobile apps for restriction-bypassed iOS devices, sued Apple alleging that Apple eliminated mobile app stores for iOS devices. https://www.washingtonpost.com/technology/2020/12/10/cydia-apple-lawsuit/, accessed on 28 March 2022.

[15] However, to use such mobile apps, consumers need to change the setting to allow the installation of apps from unknown sources. See https://developer.android.com/distribute/marketing-tools/alternative-distribution, accessed on 9 April 2022.

[16] https://searchads.apple.com/jp, accessed on April 9, 2022.

[17] https://support.google.com/google-ads/answer/6247380, accessed on April 9, 2022.

uses the app (in-app purchases). Apple and Google provide services for pay-per-download and in-app purchases as functions of the App Store and Google Play, respectively.[18]

Ad distribution services allow app developers to monetize advertising spaces in mobile apps. Mobile app developers can choose between using ad networks and setting list prices for mobile ad distribution services.

Ad networks allow mobile app developers to sell advertising spaces in mobile apps to advertisers using algorithms such as auctions.[19] Some OS producers provide ad networks. For example, Google provides Google AdMob, a major ad network.[20] Apple ran an ad network called iAD but stopped the service in 2016. [21] Ad networks provided by non-mobile OS producers include AdColony, AppLovin, and InMobi.[22][23] These four ad networks can distribute ads to mobile apps that run on Android or iOS, but there are also ad networks specifically for Android. [24]

Ad networks use the personal information of mobile app users for their ad distribution services. For example, Google AdMob provides a smart segmentation service[25] through which fewer ads are distributed to users who often use in-app purchases, and more ads are distributed to users who do not use in-app purchases very often. It also provides personalized advertising services [26] through which different ads are distributed depending on the user's interest to improve ad click-through rates. The list-price method is a monetization method in which a mobile app developer sets a list of prices for each advertisement in a mobile app to sell advertising spaces to advertisers. Mobile apps that adopt the list-price method are usually those with a certain level of customer attraction,

[18] Apple's App Store Connect Help states that the price of app downloads is specified on the App Store Connect. https://help.apple.com/app-store-connect/?lang=ja##/dev9fc06e23d, accessed on April 14, 2022. The Payments section of Google's Play Console Help states, "Developers charging for app downloads from Google Play must use Google Play's billing system as the method of payment for those transactions." https://support.google.com/googleplay/android-developer/answer/9858738, accessed on April 14, 2022.

[19] For example, AdMob adopts an algorithm in which a mobile app developer sets the lowest price to accept ads to an advertisement frame, and ads bid to the advertisement frame at prices higher than the set price displayed. https://support.google.com/admob/answer/3418058, accessed on 9 April 2022.

[20] https://developers.google.com/admob?hl=ja, accessed on 5 April 2022.

[21] https://developer.apple.com/news/?id=01152016a, accessed on April 9, 2022.

[22] Kawaguchi et al. (2022a) analyzed mobile app monetization through saling of advertisement frames using in-app advertising prices of AdMob, AdColony, AppLovin, and InMobi disclosed by Adtapsy.

[23] The Business of Apps listed 14 ad networks as the top ad networks in 2021 on its website. https://www.businessofapps.com/ads/mobile-ad-network/, accessed on April 9, 2022.

[24] AppBrain lists more than 40 ad networks for Android and their market share on its website. https://www.appbrain.com/stats/libraries/ad-networks, accessed on April 9, 2022.

[25] https://admob.google.com/intl/ja/home/resources/unlock-new-app-revenue-with-google-admob-smart-segmentation/, accessed on April 9, 2022.

[26] https://support.google.com/adspolicy/answer/143465, accessed on April 9, 2022.

such as LINE[27] and Hatena Bookmark.[28]

Some mobile apps are provided separately as complementary to the main goods or services. Such mobile apps often do not use monetization services. Examples include remote-control apps[29] for operating electrical devices, banking apps[30] to check account balances and make bank transfers, and travel apps [31] to display travel tickets and check the itinerary. Also included in this category are the COCOA[32] to detect potential COVID-19 close contacts, mobile apps such as NHK NEWS Disaster Preparedness Info[33] to improve the convenience of public services, and reader apps [34] for displaying externally purchased content, such as magazines, newspapers, books, voice records, music, and videos.

Vertical integration of Google and Apple As mentioned above, Apple provides mobile devices, mobile OS, mobile app distribution services, and services to charge consumers in its mobile app. Apple also provides mobile apps, such as parental control software and a web browser.

Google provides mobile OS, Android, mobile app distribution services, Google Play, major mobile apps, services to charge consumers in its mobile app monetization services, and ad distribution services. Google also produces Pixel, a mobile devices, although its market share is not large enough to call Google a major producer. Some Android elements are open-source, and any company can create a compatible mobile OS.

2.2 Consumer behavior in mobile app economy

This subsection describes consumer behavior in the mobile app economy.

Mobile devices and mobile OSs Consumers purchase mobile devices and use mobile apps on them. Because most mobile devices are bundled with a certain mobile OS, a

[27] LINE Business Guide (https://www.linebiz.com/jp/download/, accessed on April 6, 2022) introduced a wide range of advertising media, including those that use the list-price method and those that use the auction method. An example of monetization using the list-price method is LINE Flyer, which states a monthly base price of 1,000 yen per number of registered stores, and metered prices of 30 yen per favorite user who viewed the advertisement, and 10 yen per favorite user who did not view the advertisement.

[28] Hatena Media Guide (https://hatenacorp.jp/ads, accessed on April 6, 2022) provided the list-price, stating that "Hatena Bookmark app/General/3rd most popular" is 350,000 yen per day, and 430,000 impressions can be expected.

[29] An example of a remote-control app is HEOS (https://play.google.com/store/apps/details?id=com.dnm.heos.phone, accessed on 14 April, 2022).

[30] An example of a banking app is Shinkin Banking (https://play.google.com/store/apps/details?id=jp.shinkin.ib.banki accessed on April 14, 2022).

[31] An example of a travel app is ANA (https://play.google.com/store/apps/details?id=jp.co.ana.android.tabidachi, accessed on April 14, 2022).

[32] COCOA (https://play.google.com/store/apps/details?id=jp.go.mhlw.covid19radar, accessed on April 14, 2022)

[33] NHK NEWS Disaster Info (https://play.google.com/store/apps/details?id=jp.or.nhk.news, accessed on April 14, 2022).

[34] https://developer.apple.com/news/?id=grjqafts, accessed on April 14, 2022.

consumer's choice of mobile OS coincides with the choice of a mobile device.

Most smartphones used in Japan are shipped with pre-installed OS either Apple's iOS or Google's Android. In February 2021, MMD Labo reported the results of a mobile phone usage survey covering 40,000 men and women aged 18–69 years in Japan. The survey found that 41.0% were iPhone users and 45.8% were Android users.[35] The market share of feature phones, which had been the primary devices in Japan with local mobile OSs installed, has fallen to 6.8%, and most mobile devices currently used by consumers are smartphones that install iOS or Android.

When a consumer accesses the internet, the consumer may use a device in an adjacent market of mobile devices, such as a PC. However, mobile devices are currently the main devices for internet access. According to a survey conducted by Ministry of Internal Affairs and Communications (2021), the penetration rate of mobile devices for internet access is 68.3% for smartphones and 24.1% for tablets. It exceeds the penetration rate of PCs for internet access which is 50.4%.

Mobile apps and mobile app distribution services A consumer with a mobile device can install mobile apps using mobile app distribution services and enjoy the services provided by mobile apps.

When a consumer chooses to install a mobile app using a mobile app distribution service, they can search for the mobile app using keyword search, category search, and recommendations. In an app store, consumers can read a description of the app written by the developer, see the images posted by the developer, and obtain information on in-app purchases and advertisements. Through user reviews, consumers can also learn about other consumers' experiences of mobile app usage.

In a questionnaire survey of 3,000 consumers conducted by the Ministry of Economy, Trade and Industry, 49.5% users of mobile app stores chose Apple's App Store as the primary mobile app store in 2021, and 46.5% of them chose Google Play Store as the primary app store, indicating that most consumers mainly use mobile app distribution services provided by Apple and Google. [36][37]

Consumers may use mobile devices to enjoy internet services not only through mobile

[35] https://mmdlabo.jp/investigation/detail_1941.html, accessed on April 9, 2022.

[36] The Ministry of Economy, Trade and Industry's "2nd Monitoring Meeting on the Transparency and Fairness of Digital Platforms" Material 1 "Results of Questionnaire Survey for Digital Platform Utilization Business Firms" (https://www.meti.go.jp/shingikai/mono_info_service/digital_platform_monitoring/002.html, accessed on April 13, 2022) included the results of a questionnaire survey where 36.6% of the respondents selected "None of the above" for the mobile app store they use the most, 31.4% selected App Store, and 29.5% selected Play Store. The values 49.5% and 46.5% were calculated by dividing these values by the number of respondents who did not select "None of the above," that is, [31.4%/(100% - 36.6%)] and [29.5%/(100% - 36.6%)], respectively.

[37] While the name of Google's mobile app distribution services is Google Play, consumer services are provided through the Play Store app. Therefore "Play Store" is used when describing consumer behavior.

apps but also through web apps on a web browser. According to a Nielsen survey on smartphone use in Japan, mobile apps represented 92% and browsers 8% of the time spent using smartphones in December 2019, indicating that mobile apps are the main means for consumers to use internet services. [38]

Mobile app monetization services When a consumer decides to use a paid mobile app listed on a mobile app distribution service, the consumer pays the price to the mobile app developer through a pay-per-download service at the first download. In the App Store and Play Store, mobile app downloading rights are tied to the user account of the mobile app store. Once a consumer purchases a mobile app using an account, the consumer can download the mobile app as many times as the consumer desires on multiple devices using that account.[39]

For apps that offer in-app purchases, consumers can pay for billing services to enjoy additional features or remove restrictions on mobile app's functions. Examples of the former are the gaming app Fortnite and the matching app Tinder, and examples of the latter are the music streaming app Spotify.

2.3 Mobile app developers as users

Mobile app developers are users of mobile app distribution services and mobile app monetization services. This subsection describes the behavior of mobile app developers when using mobile app distribution services and mobile app monetization services.

Mobile app distribution services When submitting an app to a mobile app store, the mobile app developer can specify the app's category, describe the app's functions using text and images, and set the download price.[40]

Mobile app developers can use advertising services provided by mobile app stores to make it easier for consumers to find their apps. Mobile app developers use advertisements outside mobile app stores from TV ads[41] to banner ads linked to the relevant app page in the app stores. [42]

[38] https://www.netratings.co.jp/news_release/2020/03/Newsrelease20200324.html, accessed on 28 March 2022.

[39] Google Play's explanation of downloading purchased mobile apps (https://support.google.com/googleplay/answer/113410, accessed on April 13, 2022) and App Store's explanation of downloading purchased mobile apps (https://support.apple.com/ja-jp/HT211841, accessed on April 13, 2022) state that users can download apps they purchased without paying again.

[40] Google Play's explanation of downloading purchased mobile apps (https://support.google.com/googleplay/android-developer/answer/9859152, accessed on April 13, 2022), and App Store's explanation of downloading purchased mobile apps (https://developer.apple.com/jp/app-store/product-page/, accessed on April 13, 2022) state that users can download apps they purchased without paying again.

[41] In a press release, SmartNews stated that it uses TV ads for advertising its mobile apps. https://about.smartnews.com/ja/2021/02/16/20210216/, accessed on April 9, 2022.

[42] SmartNews has the banner of its app and links to the app page of mobile app stores placed on the

Mobile app monetization services Mobile app developers can monetize their mobile apps by charging consumers or selling ad spaces through mobile app monetization services. When charging consumers, a mobile app developer can set the price of additional services sold in-app and the price for downloading the app.[43] When a mobile app developer uses an ad network, the developer can create ad spaces on the app using a software development kit (SDK) provided by the ad network.[44] Mobile app developers widely use these monetization methods. According to the sample analyzed by Ghose and Han (2014), 47% of mobile apps had in-app purchases, and 66% of mobile apps displayed in-app ads.

Mobile app stores show the price for downloading and whether the app has in-app purchases. Google stated that mobile apps with in-app ads would have the "Contains ads" tags attached to them on the Play Store.[45] In contrast, the Apple App Store does not provide information about in-app ads. However, mobile app stores have consumer reviews, which often mention the nuisance of ads. Therefore, consumers can obtain partial information about in-app ads. [46]

2.4 Specified digital platforms

Apple and Google provide mobile OSs and vertically integrate various goods and services into the mobile app economy, making them special producers. The prominence of Apple and Google has led policy-makers worldwide to pay particular attention to them. In Japan, the Act on Improving Transparency and Fairness of Digital Platforms that came into effect in 2021 designated Apple and Google as "specified digital platform providers" in mobile app stores. In Europe, the European Commission enacted the Digital Markets Act (DMA), which nominates mobile app stores and mobile OSs as "core platform services" to be regulated by the Act.[47] In this study, referencing these moves, Apple and Google are collectively referred to as the "digital platforms" in the mobile app economy. This subsection identifies the conduct of these two companies, which may be potentially anti-competitive in the mobile app economy.

top page of its website.https://www.smartnews.com/ja/, accessed on April 9, 2022.

[43] The pricing of apps in Google Play is described on the "Set up your app's prices" page (https://support.google.com/googleplay/android-developer/answer/6334373, accessed on April 9, 2022). As for app pricing in App Store, the "Setting app prices" page (https://help.apple.com/app-store-connect/?lang=ja/dev9fc06e23d, accessed on April 9, 2022) states to select a price from the price table.

[44] AdMob's SDK can be obtained from Google Mobile Ads SDK (https://developers.google.com/admob, accessed on April 9, 2022).

[45] https://support.google.com/googleplay/android-developer/answer/9859455, accessed on April 9, 2022.

[46] For example, the LINE app product page on App Store (https://apps.apple.com/jp/app/line/id443904275, accessed on April 9, 2022) has no information on ads provided by the mobile app store or developer but shows a user review titled "Too many ads. Barely usable," accessed on April 9, 2022.

[47] https://eur-lex.europa.eu/legal-content/en/TXT/?uri=COM:2020:842:FIN, accessed on April 9, 2022.

2.4.1 Conducts in mobile app distribution

Digital platforms determine the choices that mobile app developers can make using the terms of service of their mobile app distribution services. Apple controls how mobile app developers distribute apps through its App Store Review Guidelines, which are arranged into five sections: Safety, Performance, Business, Design, and Legal. In the Guidelines, Apple lists the grounds for prohibiting the distribution of some apps through the App Store, including safety for the kids, respect for users with differing opinions, and the quality of the app experience, and attempts to cheat the system.[48] Google defines "Mobile Unwanted Software," and lists "Transparent behavior and clear disclosures," "Protect user data," and "Do not harm the mobile experience" as the principles that mobile app producers should follow in distributing their apps. [49]

Digital platforms can eliminate certain apps by changing the terms of service of their mobile app distribution services. For example, when it released a screen-time monitoring feature with iOS12, Apple deleted several mobile apps from its mobile app store that provided features similar to the new feature of iOS12. Apple was questioned about the reason for this conduct in a hearing in the U.S.[50]

As digital platforms run both mobile app distribution and mobile app businesses, they can bundle their mobile apps to their mobile OS using their mobile app distribution services, place their products in prominent positions compared to other companies' products, and observe the sales of other mobile app developers to utilize that information for their mobile app development. Such conduct is called "self-preferencing."[51]

2.4.2 Conducts in mobile app monetization

Digital platforms provide mobile app monetization services for in-app purchases distributed through their mobile app distribution services. Apple states in its App Store Review Guidelines that apps cannot use their billing systems.[52] Google states in the Payments section of its Developer Program Policy that Google Play's billing system must be used to charge for app downloads. It also states that Google Play's billing system must be used for payments for in-app purchases unless Section 3 or Section 8 applies. Section 3 provides provisions for apps that cannot use in-app purchases, including those for purchasing or renting physical goods. Section 8 stipulates the procedure for using

[48] Apple shows a list of five sections and "a few points to keep in mind" in the introduction of the App Store Review Guidelines. (https://developer.apple.com/jp/app-store/review/guidelines, accessed on April 14, 2022).

[49] https://support.google.com/googleplay/android-developer/answer/9970222?hl=jaref_topic=9969691, accessed on April 14, 2022.

[50] https://techcrunch.com/2020/07/29/apple-ceo-tim-cook-questioned-over-app-stores-removal-of-rival-screen-time-apps-in-antitrust-hearing/, accessed on March 28, 2022.

[51] For the examples of self-preferencing, see Kittaka et al. (2022).

[52] https://developer.apple.com/jp/app-store/review/guidelines, accessed on 9 April 2022.

an external billing system when requiring or accepting payments from users in South Korea.[53]

On March 23, 2022, Google Play started piloting with Spotify service to allow external billing systems for in-app purchases in apps downloaded from Google Play.[54] It also expanded the pilot program to app developers in pilot countries on September 1, 2022.[55]

In addition, digital platforms have included anti-steering provisions in their policy to prohibit users of its mobile app distribution services from bypassing its specified billing method. Anti-steering provisions in the mobile app economy prohibit app developers from steering users to a web app through links, texts, or images.

Apple states in the App Store Review Guidelines that "Apps and their metadata may not include buttons, external links, or other calls to action that direct customers to purchasing mechanisms other than in-app purchase," except for those that can be recognized as "reader" apps under the terms of Apple. [56] The exceptional measure for "reader" apps was set forth on March 30, 2022, in line with Apple's proposition to revise the guidelines during an investigation by the Japan Fair Trade Commission (JFTC) published on September 2, 2021. [57][58][59]

Google states in Section 4 of its payment policy that "Other than the conditions described in Section 3 and Section 8, apps may not lead users to a payment method other than Google Play's billing system." This prevents app developers from leading consumers to make transactions other than in-app purchases.[60]

With certain billing services enforced by digital platforms, a commission is applied to pay-per-download and in-app purchases in mobile app distribution services. As of March 2022, both Apple and Google set a commission of 30%, except in some exceptional cases such as discounts for small-scale businesses and subscription services.[61] This value is higher than the commission of 12% set for Epic Game Store and 9% for "i-mode" which was the dominant mobile app distribution service at the time of 3G mobile communication in Japan.

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[53] https://support.google.com/googleplay/android-developer/answer/9858738, accessed on November 22, 2022.

[54] https://android-developers.googleblog.com/2022/03/user-choice-billing.html, accessed on November 22, 2022.

[55] https://support.google.com/googleplay/android-developer/answer/12570971?hl=en, accessed on November 22, 2022.

[56] https://developer.apple.com/jp/app-store/review/guidelines, accessed on April 14, 2022.

[57] https://www.jftc.go.jp/houdou/pressrelease/2021/sep/210902.html, accessed on April 14, 2022.

[58] https://developer.apple.com/jp/news/?id=grjqafts, accessed on April 14, 2022.

[59] https://developer.apple.com/jp/support/reader-apps/, accessed on April 14, 2022.

[60] https://support.google.com/googleplay/android-developer/answer/9858738, accessed on November 22, 2022.

[61] For the commission Apple charges, the following website shows that the standard commission of the App Store is 30%. https://www.apple.com/newsroom/2020/11/apple-announces-app-store-small-business-program/, accessed on April 14, 2022. The commission that Google charges can be checked on the following website: https://support.google.com/googleplay/android-developer/answer/112622, accessed on April 14, 2022 .

Apple has specified in its App Store Usage Rules that mobile app developers must select a price from a price table set by Apple, implying that Apple does not allow app developers to set a flexible price. Apple obligates the use of an App Tracking Transparency API that requires app developers to obtain user permission whenever the app developer tracks users across apps or websites to gather and use personal data for ad distribution.[62]

On February 17, 2022, Google announced a multi-year initiative to build Privacy Sandbox, a new ad distribution solution to replace conventional methods based on cross-web or cross-app user tracking. This requires the correction or replacement of existing ad distribution services. Therefore, Google is expected to work closely with the industry and governments to proceed with the initiative.[63]

2.5 Issues of market power assessment in mobile app economy

When assessing the conduct of digital platforms, such as Apple and Google, in the mobile app economy, several steps for economic analysis need to be taken.

First, it is necessary to analyze how mobile apps are perceived by users, such as consumers and advertisers, of mobile apps as goods in the mobile app economy and its adjacent markets. Second, it is necessary to analyze how mobile app developers perceive mobile devices and mobile OSs as goods in the mobile app economy and its adjacent markets. Finally, it is necessary to analyze the incentives of digital platforms such as Apple and Google to use their conduct in anticipation of reactions by such mobile app users and developers.

Regardless of the level of sophistication of such economic analysis in a specific case, market definition and evaluation of the market power of mobile apps are essential in practice. However, in the first step of economic analysis, several issues specific to the mobile app economy must be considered. Below are examples of competition law cases shown to help understand these issues.

Review of managerial integration of Z Holdings Corporation and LINE Corporation by JFTC In August 2020, the JFTC reviewed the proposed M&A operations between Z Holdings Corporation and LINE Corporation and decided to approve the M&A operations.[64]

The merging parties are mobile app developers. Z Holdings Corporation is a group of combined companies owned by the parent company SoftBank Group Corporation. Its subsidiary, Yahoo Japan Corporation, provides news distribution services through Yahoo!

[62] The App Store Review Guidelines "5.1.2 Data Use and Sharing" describes the restriction. https://developer.apple.com/jp/app-store/review/guidelines/, accessed on April 14, 2022.

[63] Privacy sandbox is a collective term for several technologies to replace user tracking and how to realize that with what kind of technologies are still being deliberated. https://japan.googleblog.com/2022/02/privacysandboxonandroid.html, accessed on April 14, 2022.

[64] https://www.jftc.go.jp/houdou/pressrelease/2020/aug/200804.html, accessed on March 28, 2022.

JAPAN app and Yahoo! News app. In addition, its subsidiary, PayPay Corporation, produces a code-based payment app, PayPay. LINE Corporation is a group of combined companies held by the parent company NAVER Corporation. LINE Corporation provides messaging and news distribution services on its LINE app, and its subsidiary, LINE Pay Corporation, produces a code-based payment app, LINE Pay. Both Z Holdings Corporation and LINE Corporation are influential mobile app developers in the Japanese market. In the 2019 ranking of the number of active monthly users released by AppAnnie (2020), LINE, an app provided by LINE Corporation, held the 1st place, and Yahoo! JAPAN, Yahoo! Weather, and Yahoo! Japan Transit, apps provided by Z Holdings Corporation, were ranked 4th, 6th, and 9th, respectively, in the non-game app category.

In the review, the JFTC defined relevant markets in the fields of "news distribution service", "advertisement-related business" and "code-based payment service" as the fields of trade in which the merging parties are competing or trading.

For each field, the JFTC examined the demand substitutability and supply substitutability based on the nature of the business and hearings, "free news distribution services" as the relevant market for news distribution service; "non-search advertising business," "intermediation service of specific digital advertisement where advertising clients/advertising agencies are users," and "intermediation service of specific digital advertisement where media companies are users" for advertisement-related business; and, "code-based payment services where consumers are users" and "code-based payment services where member stores are users" for code-based payment services. However, the JFTC did not analyze the influence of the merger of Z Holdings Corporation and LINE Corporation on the mobile app market or the mobile app monetization services.

Based on the results of the market definition above, the JFTC judged that the merger would not substantially lessen competition and decided to approve the merger without remedies other than those for the code-based payment service proposed by the merging parties.

In this review of transactions, the first issue is defining the relevant markets in two-sided markets. Specifically, the merger involves two-sided platforms because "news distribution service" and "advertisement-related business" put the viewers and advertisers together. The code-based payment services match the "consumers" and "member stores." The JFTC separately defined markets for news distribution services, advertisement-related businesses, code-based payment services where consumers are users, and code-based payment services where member stores are users. However, when defining the relevant market and evaluating the market power of goods and services that face multiple markets for consumers and advertisers, such as mobile apps, the market power of multiple businesses needs to be assessed simultaneously. The second issue was the assessment of the competitiveness of code-based payment services, in which profits come from adjacent markets. More discussions are needed to determine how to conduct market definitions and market power assessments in such situations.

Epic Games, Inc. v. Apple Inc. in U.S. District Court for California The second example is a lawsuit filed by Epic Games against Apple. In this case, the question was whether Apple's goods and services were in a monopoly position.

In August 2020, Epic Games filed a lawsuit against Apple, alleging Apple's violations of antitrust laws and California's Unfair Competition Law regarding Apple's App Store rules that charge 30% of in-app purchases and prohibit the use of payment systems outside Apple's system. [65] Epic Games claimed that Apple was exerting monopoly power in the mobile app distribution and in-app payment markets. The high commission maintained by such monopoly power caused an increase in the price of mobile apps and stagnation of innovation by mobile app developers due to reduced development expenses.

One of the main issues was whether Apple was in a monopoly position. Epic Games defined the entire mobile OS market as the foremarket and the mobile app distribution and monetization service markets as the aftermarkets. Based on this definition, Epic Games argued that while Apple might not have had a monopoly in the foremarket, Apple was exerting monopoly power in the aftermarkets consisting of relevant markets formed by the iOS app distribution and payment processing service markets. In contrast, Apple claimed that the entire video game market including digital mobile games, PC games, console games, and cloud streaming games was the relevant market for the mobile app distribution service. Apple was not the monopolist in mobile app distribution and monetization services. Apple also claimed that a 30% commission level is necessary to ensure transaction safety.

Regarding the definition of relevant markets, both sides used expert testimony accompanying data analysis by economics and business administration experts to prove the presence or absence of the substitutability of smartphone choice by consumers and game use by holders of multiple game devices. However, the judge did not adopt either side of the conclusions in defining relevant markets, stating that the expert testimony on both sides lacked validity.

In September 2021, the U.S. District Court for the Northern District of California dismissed the definition of aftermarkets by Epic Games and subdivided the video game market suggested by Apple. Specifically, the Court defined the relevant market of the App Store as a digital mobile gaming transaction market consisting of Apple App Store, Google Play Store, Samsung Galaxy Store, and other similar stores and ruled that Apple was not in a monopoly position in that market. Regarding mobile app monetization services, the Court ruled that the digital mobile gaming transactions market had substitutable stores, and competition existed even for in-app purchases.

[65] https://cand.uscourts.gov/cases-e-filing/cases-of-interest/epic-games-inc-v-apple-inc/, accessed on 28 March 2022.

Independent of the above decisions on the market definition and the evaluation of market power, the Court ruled that the anti-steering provisions set by Apple violated California's Unfair Competition Law and ordered Apple as a remedy to allow providing links ("outlinking") to direct users to websites with external billing functions in mobile apps.

In this case, substitutability between different smartphones and substitutability between smartphones and gaming devices in game use were argued to define the markets. As in this example, when defining the market of mobile apps, including substitutability among different mobile devices/mobile OSs and substitutability with the software on different mobile devices/mobile OSs belonging to adjacent markets, the substitutability needs to be assessed using multiple margins such as the choice of devices and OSs, and app usage.

However, there are two critical differences between the two cases. First, in this case, the users were consumers and member stores, and those in the other case were consumers and advertisers. Second, the profit structure of this case comes from consumer payments and advertising, and that of the other case comes from consumer payments and merchant fees.

Case of Netherlands Authority for Consumers and Markets' action against Apple On August 24, 2021, the Netherlands Authority for Consumers and Markets (ACM) decided that Apple's imposition of anti-steering provisions on dating-app developers was unreasonable and was an abuse of its dominant position and judged that Apple violated the Dutch Competition Act and EU competition law. In response, Apple appealed to the Rotterdam District Court to revoke the decision by ACM, but on December 24 of the same year, the Court dismissed Apple's request. ACM defined the iOS app distribution market as relevant market and judged that Apple had a dominant position as the sole app distributor in the market.[66]

ACM judged that multi-homing iOS and Android is critical to dating-app developers and defined the relevant market of mobile app distribution services based on that factual understanding. As the reasons for judging multi-homing as critical, ACM listed the following circumstances: 1) in a dating app, the direct network effects arising from improved odds of a successful match with other users are important, and the mobile app needs to be provided to as many users as possible; and 2) most dating app users are single-homing iOS or Android, and multi-homing is essential to widen the reach of the dating app. In addition, ACM pointed out that, regardless of reality, many consumers assume that the reach of their dating app is not limited to the mobile OS each consumer uses so that they can meet users of the mobile app installed on another mobile OS. Therefore, dating apps

[66] https://www.acm.nl/en/publications/summary-decision-abuse-dominant-position-apple, accessed on 28 March 2022.

must acquire users across mobile OSs to gain direct network effects. ACM did not explicitly state the reason developers' multi-homing is important in determining the iOS app distribution market as the relevant market. Most likely, ACM may have considered that no substitutability exists between iOS and Android under circumstances where mobile app developers are multi-homing.

Regarding the fact that Apple did not allow the use of mobile app distribution services other than the App Store for Apple's devices such as the iPhone, ACM determined that Apple restricted the freedom of choice concerning the processing of payments for digital content and services, which corresponded to abuse of a dominant position.

To restore competition in mobile app monetization services in dating apps, ACM ordered Apple to take the following two remedial measures: to allow the use of billing systems other than the billing system of the App Store and to allow dating app developers to offer external payment methods in their mobile apps.

In this case, the discussion that played a core role in market definition was that single-homing by consumers made it necessary for dating-app developers to multi-home, which in turn weakened competition between mobile OSs and developers. As demonstrated by this case, the homing structure of consumers and developers sometimes plays an important role in the market definition, and market definition and market power assessment, taking into account the homing structure of consumers and developers, will be necessary.

Issues Based on the discussions above, the following section discusses the substitutability in mobile devices, mobile OSs, and mobile apps from the viewpoints of consumers and advertisers and the substitutability in mobile devices and mobile OSs from the viewpoints of developers. Specifically, consumers' choices will be divided into mobile OS choice and mobile app use, and developers' choices will be divided into mobile app development and mobile app monetization. We discuss the substitutability of each decision making. Next, we discuss the case in which a mobile app developer has market power in the advertising market, the issues related to the two-sidedness of mobile OSs, and the effects of the consumer homing structure on the choices made by consumers and app developers.

We then propose specific empirical methods for defining relevant markets and evaluating the market power of mobile apps. Based on the institutional background and theoretical considerations, we discuss how to address the issues of the two-sidedness of mobile apps and potential competition with adjacent markets such as browsers and console games. Note that this study focuses on market definition and evaluation of market power concerning mobile apps, and assessment of the anti-competitiveness of digital platform conducts is beyond the scope of this study.

3 Theoretical Consideration

In this section, we discuss the behaviors of consumers and developers relevant to market definition and evaluation of market power in the mobile app economy.

In the literature on the mobile app economy, or two-sided markets in general, the choices of consumers and developers are often divided into membership and usage choices (e.g., Rochet and Tirole, 2006; Gans, 2012; Gaudin and White, 2021). By regarding mobile OSs and the OSs in adjacent markets as platforms, we discuss the membership and usage of these OSs by consumers and developers.

On the consumer's side, we regard "OS choice" and "app usage" as consumer's membership and usage choices, respectively. OS choice is the consumer's choice to obtain a device necessary for using certain apps. Concerning the classification made in Section 2, it is the choice of goods and services from the product groups "mobile devices" and "mobile OSs" or from the product groups in the adjacent markets of "mobile devices" and "mobile OSs," such as PCs and game consoles. App usage refers to the consumer's choice to download and use an app via an app distribution service within a platform. Concerning Section 2, it is a choice of mobile apps through mobile app distribution services, or other goods and services from adjacent markets, such as web apps.

On the developer's side, we regard the app developer's "app development" and "app monetization" as membership and usage decisions, respectively. App development is literally the app developer's choice to develop apps that run on specific OSs including iOS and Android, web apps, and other apps. App monetization is the choice of monetization scheme for a specific app using app monetization services such as billing and ad distribution services.

Consumers' OS choices, app usage, app developers' app development, and app monetization vary depending on the homing structure of the consumers and developers (e.g., Lee, 2013; Anderson et al., 2018; Bakos and Halaburda, 2020; Liu et al., 2021). In other words, a consumer's choice depends on whether developers develop apps that run on only one OS (single-homing) or multiple OSs (multi-homing). A developer's choice also depends on whether consumers choose one OS only (single-homing) or multiples OSs (multi-homing). In the next subsection, we give theoretical considerations to consumers' and developers' decision-making, assuming that consumers are single-homing and developers are multi-homing as depicted in Figure 1, which is a typical situation in the mobile app economy.[67]

Afterwards, we further discuss the effects of consumer multi-homing on the use of platforms.

[67] Indeed, a survey by Bresnahan et al. (2015) on 1,231 mobile app samples in the U.S. found that 64% of mobile apps were multi-homing.

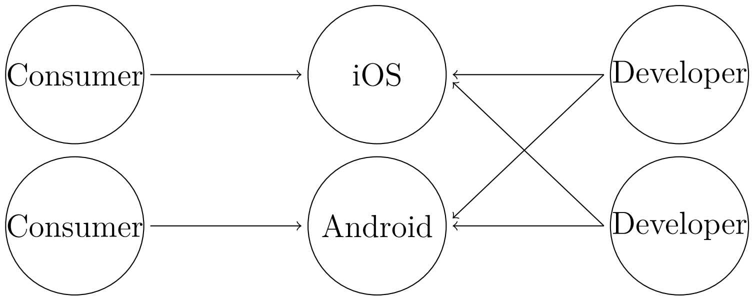

Figure 1: Typical homing structure. An arrow from consumer to OS means selection of the OS. An arrow from developer to OS means development of apps that run on the OS.

3.1 OS choice and app usage by consumers

This subsection discusses a consumer's OS choice and app usage. For a moment, we assume that consumers single-home and app developers multi-home. Later, we discuss the implication of the different homing structures.

OS choice First, we consider consumers' OS choices. In the current mobile app economy, a mobile OS is pre-installed on a mobile device, as described in Section 2. The same applies to adjacent markets such as gaming consoles. Therefore, consumers can use apps that run on a specific OS by owning devices that install the OS.

A consumer's utility from owning an OS consists of the expected utility from the apps available on the OS. Specifically, a consumer's utility from owning a device that installs a certain OS is determined by several factors including: the number, price, and quality of the apps available on the OS; the price and quality of the device; and additional services provided by the OS.

When a consumer single-homes, the consumer purchases a device with an OS that provides the greatest utility from owning the OS. If two OSs are substitutable, then a reduction in the consumer's utility from owning a device induces some consumers to switch to another device.

The leading mobile OSs chosen by consumers are iOS and Android. Therefore, when evaluating the market power of OSs in the current app economy, the substitution between iOS and Android plays an important role. Regarding this point, Grzybowski and Nicolle (2021) estimated the switching costs in the choice of mobile devices by using consumer-level panel data on the purchase of mobile devices. To estimate switching costs, Grzybowski and Nicolle (2021) exploited the difference in the mobile device purchasing behavior of consumers who held the different devices in the previous month. According to the estimates, the costs of switching from iOS to other OSs were higher than those for switching between other OSs, indicating a low substitutability between iOS and other OSs.

When consumers view mobile OS as substitutable with other OSs, competition between mobile OSs will be extended to such OSs. For example, when a Windows PC or macOS PC is mutually substitutable with a smartphone for a consumer, these devices are considered to be in a competitive relationship.

App usage Next, we discuss app usage by consumers. Once a consumer has a device that installs a certain OS, she can install and use an app that meets a certain need. The consumer installs and uses the app when the utility obtained by using the app is greater than the utility obtained from the other options. If multiple substitutable apps are available, the consumer uses the app that maximizes her utility. The consumer's utility from using an app depends on the quality, download prices, in-app purchases, and advertising intensities. For example, Ghose and Han (2014) estimated the demand for mobile apps using ranking data on mobile apps for iOS and Android and found that demand is higher for mobile apps with in-app purchases and frequent updates, and demand is lower for mobile apps with in-app ads. In addition, the information provided in app stores affects consumers' app usage. Specifically, Ghose and Han (2014) found a positive association between the number of downloads of mobile apps and the length of the description and the number of reviews in the mobile app store. Carare (2012) found a positive association between the number of downloads of apps and the past rankings on the mobile app store.

When a consumer single-homes, the consumer has only one OS to use apps, and there is no competition between OSs regarding app use. Meanwhile, when a similar service is available in an adjacent market, the consumer can choose whether to use a mobile app on a mobile OS or a similar service in an adjacent market. Examples of such external means include web apps on web browsers and game software on consoles, such as Nintendo Switch.

When a consumer is about to use an app, competition among app distribution services may occur, depending on the OS. As discussed in Section 2, in the current mobile app economy, when a consumer is about to use an app on iOS, only the App Store is an available mobile app distribution service. Therefore, there is no competition in the mobile app distribution service on iOS. However, when a consumer uses a mobile app on Android, the consumer can select from multiple mobile app distribution services to download the app. Therefore, substitutability among such services may exist if the prices or qualities of the mobile apps differ across app distribution services.

Implications on market power assessment As discussed above, there are two margins of competition among mobile OSs, namely, the margin of OS choice and the margin of app usage. The importance of each margin depends on the nature of conduct that poses a problem in competition policy. For example, a conduct that affects competition among apps in a minor category may only affect app usage, without affecting the OS choice.

Meanwhile, a conduct that affects apps that are highly important to all consumers (e.g., browsers) or a conduct that affects all apps in every category may affect not only app usage but also OS choice.

Consumer multi-homing When consumers are single-homing, competition between mobile OSs occurs in OS choice, but not in app usage. In contrast, when consumers are multi-homing, the way competition exists between mobile OSs in mobile OS choice and in mobilethe app use varies.

When consumers are multi-homing, the competition in OS choice becomes weaker because consumers can select both iOS and Android if both of them provide high utility levels. However, when consumers are multi-homing, the competition between OSs becomes stronger in app usage for the following reasons. When a consumer chooses to use an app to satisfy a certain need, the consumer can use it through multiple OSs. Therefore, competition between OSs occurs in app use by multi-homing consumers.

Therefore, consumer multi-homing may be considered as a factor that shifts the margin of competition between OSs from OS choice to app use (Calzolari and Denicolò, 2013; Sato, 2021).

3.2 App development and monetization by app developers

App developers decide to develop an app that runs on a specific OS, and choose a monetization scheme for the app including pricing and advertising.

App development App developers decide to develop an app that runs on a specific OS at a certain development cost. When consumers are single-homing, even if a developer develops an app that runs on multiple OSs, consumers who use the app on one OS differ from those who use the same app on a different OS. Therefore, incentives for an app developer to develop an app that runs on a certain OS are independently determined for each OS. A developer develops an app that runs on an OS if the expected additional profit from developing the app is greater than the cost for developing the app. The expected profit from developing the app is determined by the number of consumers who choose the OS and the per-consumer profit of the app. Some empirical studies have reported that the expected profit from consumers indeed affects the app development incentives. For example, Wen and Zhu (2019) reported that the threat of a mobile OS provider's entry into a certain category reduces the number of updates of the apps in that category.

Under the assumption of consumer single-homing, app development incentives for app developers are independent across OSs. In this case, competition between OSs in terms of app development does not exist or is weak.

App monetization App developers decide how to collect revenue from app users via app monetization services. Specifically, an app developer attempts to earn money out of its app by specifying prices for pay-per-download or in-app purchases or displaying ads in the app. Such monetization methods by app developers depend on some variables including monetization-related agreements (e.g., commission) set by an app store and the additional values of transactions using a mobile OS.

Regarding the OS substitutability in the app monetization, if consumers are single-homing, changing the app monetization method for an app that runs on one OS does not affect how consumers use the same app that runs on the other OS. Therefore, each app developer decides on app monetization for each OS independently. For that reason, competition does not occur between OSs when it comes to app monetization. Therefore, substitutability does not exist between OSs for app monetization.

Meanwhile, substitutability does exist among app monetization services. For example, developers who provide apps for an OS that charges higher payment fees have stronger incentives to divert transactions to outside the apps by using a cheaper payment service in an adjacent market or changing the business model to have an advertisement-based profit structure rather than a payment-based profit structure (Gans, 2012; Kawaguchi et al., 2022a; Zennyo, 2021).

Consumer multi-homing As we have discussed, when consumers single-home, competition between OSs for app development and app monetization by app developers is weak, or does not exist. However, consumer multi-homing alters the app developers' incentives for app development and app monetization.

When consumers multi-home, an app developer only has to develop an app that runs on one of the OSs to deliver the app to consumers. Therefore, compared to the case of consumer single-homing, consumer multi-homing lowers the developer's incentive to multi-home (e.g., Liu et al., 2021). In addition, if both consumers and app developers are multi-homing, app developers can to steer the consumers to use apps on one of the OSs by raising the price or increasing the advertising level of the apps on the other OS (e.g., Johnson, 2017). Therefore, when the commission of an app distribution service or app monetization service for one OS increases, substitution in consumers' app use may occur through a change in a developer's app monetization schemes.

For this reason,competition between OSs will likely become stronger in app development and monetization in an environment where many consumers multi-home.

The determinants of homing structure are open questions. The literature on platform economics suggested a technical restriction in the form of high consumer multi-homing costs and exclusive agreements between platform business operators and developers as reasons for a specific homing structure (e.g., Liu et al., 2021; Ishihara and Oki, 2021). In the mobile app economy, exclusive agreements for app developers are not very common, and consumers do not receive much benefit by having multiple smartphones, which may explain the reason why many consumers single-home and many developers multi-home.

Meanwhile, even if consumers multi-home, if consumers' app usage is locked into one OS, then the discussion above does not hold. For example, suppose consumers are determined to use iPhone for mobile apps in certain categories and Android for mobile apps in other categories. In that case, mobile app developers cannot affect the consumers' app usage behavior. In this case, competition is unlikely to occur between mobile OSs regarding consumers' app usage (Sato, 2021).

3.3 Welfare assessment of advertising market

Advertisers are also important economic agents in the mobile app economy. Advertisers can make their existence, products, or services known to consumers by placing ads on mobile apps. By doing so, the advertisers make profits. When considering placing ads on mobile apps, an advertiser compares the unit cost of ads with the profit it can make by showing ads to users of the apps, and places ads when the profit is greater than the cost.

While ads bring disutility to consumers, advertisers gain profits by showing ads. This structure often generates an effect called see-saws (Anderson and Peitz, 2020). See-saws mean that the advertiser welfare tends to be hurt when the consumer welfare has been improved by a change in competitive environments, and vice versa. For example, if a merger between app developers lessens the competition for consumers and increases ad exposure, the consumers will be hurt, but the advertiser welfare improves. Similarly, if an app developer's entry into the market intensifies competition for consumers, the consumer welfare would improve, but the advertiser welfare may be hurt because of reduced ad exposure.

This welfare property also depends on the app developers' market power in the advertising market. When an app developer has market power in the advertising market, the developer may set advertising rates higher than efficient levels, resulting in an insufficient supply of advertisements (e.g., Anderson and Coate, 2005; Sato, 2019). In this case, an increase in ad exposure due to a merger, etc. may improve the welfare in the advertising market.

3.4 Two-sidedness, and complementarity among products and services

This subsection discusses the two-sidedness of OSs and the complementarity of multiple services provided by OSs as particularly important elements in discussing the market power of OSs. Note that the two-sidedness of OSs concerns consumers and developers, different from the two-sidedness of apps facing consumers and advertisers.

First, we discuss the two-sidedness of OSs. As discussed, the incentive for a consumer to choose a specific OS depends on the number of apps that run on that OS. The incentive for an app developer to develop an app depends on the number of consumers who use the OS. Therefore, an OS with more users and apps can offer more value to consumers and app developers than other OSs. An OS with a large customer base can easily prevent consumers and app developers from using other OSs due to that very fact.

We now discuss the complementarity among multiple services provided by platform operators. In addition to mobile OSs (iOS and Android) and compatible mobile OS devices, Apple and Google offer products that are highly complementary to them, such as smart watches (e.g., Apple Watch, Fitbit) and laptop PCs (e.g., Mac Book, Chrome Book). If a consumer enjoys the benefits of using multiple products offered by one platform operator, the consumer may choose an OS and use apps not only based the utility of an OS alone but also by considering the complementarity among multiple products. In this case, the substitutability between OSs at the time of OS choice and app development may weaken, and the substitutability between OSs and other competing services in app usage and app monetization may also become weaker.

4 Empirical Methods

Section 3 examines the margins at which competition for consumers and app developers can occur. In theory, competition for consumers could occur for mobile OS choices and app usage among mobile OSs and goods in adjacent markets. Competition for developers can occur for app development and monetization among mobile OSs and goods in adjacent markets. The consumer's and developer's homing structure and the rules set by digital platforms determine the conditions of competition.

Thus, when assessing the market power of mobile apps, mobile devices, and mobile OSs, we must assess the various actions consumers and mobile app developers can take. However, it is not easy for an antitrust authority to observe all the decisions made by mobile app developers. Therefore, this section discusses a method to assess the market power of mobile apps and digital platforms, which can be implemented by observing only the decisions made by users of mobile apps, such as consumers and advertisers, based on the theoretical considerations in the preceding section.

By extending the model, we also cover the assessment of competition between mobile OSs and goods in adjacent markets, such as browsers and game consoles. To this end, we consider a situation where two mobile OSs, iOS and Android, compete for the margins of mobile OS choice and mobile app usage by consumers. We do not consider competition for payment method choice.

In this section, we propose a novel method to define the relevant market and assess the market power of mobile apps derived from the principles of relevant market definition and market power evaluation rather than a review of existing methods. We employ the concept of consumer disutility in Kawaguchi et al. (2022a) to apply the hypothetical monopolist test (Ivaldi and Lorincz, 2011) and upward pricing pressure (Shapiro, 2019) to two-sided markets, including free goods that do not charge consumers a price. Then, we extend some dimensions, such as competition with goods in adjacent markets, but omit other aspects, such as mobile app usage time, considering the constraints in the actual policy analysis.

4.1 The case of perfectly competitive advertising market

First, we consider a case in which the advertising market can be regarded as perfectly competitive. In this case, mobile app developers determine the number of ads shown to consumers by taking the market price of the advertisement. This assumption is, of course, not realistic. However, if the focus is on the competition between two large mobile OSs and between mobile app stores and not on the welfare analysis of advertisers, then it would be convenient to simplify the decisions of mobile app developers in the advertising market. The indirect network effect between consumers and advertisers is simplified, yet it plays some role in this model.

A consumer survey can be purchased from a private marketing research company or conducted. To use this approach, we need data on i) mobile OS choice (iOS, Android, or both) and ii) installed mobile apps at the consumer and year levels, i) download price, ii) average in-app purchase, and iii) average advertisement number at the mobile app and year levels. We need data for at least two periods to address the possible lock-in effect on an owned mobile OS. The required sample size depends on the penetration rate of target apps. For example, if the penetration rate of the target apps is 5%, then an approximate sample size of 10,000 is required to ensure at least 500 users for each app. We need to consult ad technology firms and mobile app developers for the mobile app advertisement number and price data. If we focus on a few mobile apps, we can scrape the data using the developer's tools for mobile apps.

Let $\mathcal{J}_{iOS,t}$ and $\mathcal{J}_{And,t}$ denote the set of iOS and Android apps, and let $\mathcal{J}_t = \mathcal{J}_{iOS,t} \cup \mathcal{J}_{And,t}$. Consumer i's mobile OS is $w_{it} \in \{iOS, Android, Both\}$, the installed apps are $D_{it} \subset \mathcal{J}_t$, and the sum of app j's download price and average in-app purchases is a_j. Similar mobile apps offered by different mobile OSs are assigned different indices. The mobile OS for app j was $o_j \in \{iOS, Android\}$. The other observable characteristics of app j are x_{jt}.

We use the data of the first period, $t = 1$, to measure the degree of the lock-in effect on the mobile OS and the second-period data for the demand estimation. Using this data, we estimate a discrete choice model of consumers for mobile apps. Specifically, we capture the lock-in effect by estimating different parameters for each mobile OS used in the first period w_{i1}. That is, we assume that the indirect utility for consumer i of downloading mobile app j in the second period is:

$$u_{ij2} = \beta_i' x_{j2} + \sum_o \gamma_{io} 1\{o_{j2} = o\} - \alpha_e e_{j2} - \alpha_a a_{j2} + \epsilon_{ij2}$$

and the coefficients are defined as functions of w_i as

$$\beta_i = \sum_w 1\{w_{i1} = w\}\beta_w,$$

$$\gamma_i = \sum_w 1\{w_{i1} = w\}\gamma_{wo},$$

where ϵ_{ij2} is the preference shock of consumer i for mobile app j in the second period (the distribution is specified later).

In this model, the parameter γ_{w0} captures the difference in the utility of apps for different OSs between consumer i's mobile OS in the first period, w_{i1}. From the consumer's perspective, these parameters determine the degree of substitution between the apps of different mobile OSs. If there is a lock-in effect for a specific mobile OS, then consumers with $w_{i1} = iOS$ or $w_{i1} = Both$ would receive higher utility for iOS apps than consumers with $w_{i1} = Android$. Then, $\gamma_{iOS,iOS}$ and $\gamma_{Both,iOS}$ would take higher values than $\gamma_{And,iOS}$. If consumers single-homing to iOS are more locked-in to iOS than multi-homing consumers, then $\gamma_{iOS,iOS}$ would take a higher value than $\gamma_{Both,iOS}$.

This is a minimal setting for capturing substitution between mobile OSs. By incorporating the other statistics of consumer behaviors in the first period that could influence the lock-in effect in the second period, we can more accurately examine the substitution between mobile OSs. For example, based on the mobile apps installed in the first period, we can construct the overall number of installed apps by category for the first period. Letting z_i denote the observed characteristics of consumer i in the first period, including the mobile OS choice w_{i1}, we can extend the random-coefficient model of the second period as:

$$u_{ij} = \beta_i' x_j - \alpha_e e_j - \alpha_a a_j + \epsilon_{ij},$$

$$\beta_i = \beta_0 + \Pi_\beta z_i.$$

We suppressed the index $t = 2$ for notational simplicity. All of the following analyses focus on decisions in the second period. The information from the first period is summarized as consumer characteristics z_i.

The parameter Π_β captures how the consumer's demand for mobile apps in the second period could differ according to mobile app choice and usage in the first period. For example, if z_i includes the number of installed iOS apps in the first period, then it can quantify how much the substitution for Android apps could decline when a consumer used more iOS apps in the first period. If we are interested in substitution among specific apps, then we can survey the characteristics that are important for the apps. For example, if we are interested in the lock-in effect on photography apps, we can survey the number of apps saved in iCloud and Google Photo.

Rigorously speaking, there are problems in using the statistics of consumers' first-period behavior as a covariate for estimating the lock-in effect in demand for the second period. For instance, even if a consumer who used iOS in the first period tended to use iOS more in the second period, we could not distinguish whether this was because the consumer specifically preferred iOS or because the lock-in effect played a role. Notwithstanding such flaws, this would still help analyze the overall lock-in effect.

Given the indirect utility function, we consider how to model the consumer's problem and estimate the parameters of indirect utility. However, we face several modeling issues. First, there is a sequential decision process, such that the consumer chooses whether to multi-home or single-home, which mobile OS to use, and then decides which mobile apps to download and install. Second, the decision has a combinatorial nature, such that the consumer installs multiple apps, and the apps can be either substitutes or complements. Third, there are mixed business models, such that mobile apps can earn revenue by charging download prices and in-app purchases or by showing advertisements to consumers. The modeling strategy depends on how these issues are addressed.

For the first issue, a natural approach is to use a nested model. In the first step, the consumer chooses the mobile OSs from $\mathcal{W} = \{iOS, Android, Both\}$, and in the second step, they choose the apps to install given the choice of mobile Os in the first stage. To fully address the second issue of the combinatorial problem, we may have to adopt the framework of multicategory competition (Thomassen et al., 2017). However, this approach is still under development and not yet ready for practical use. Hence, in this study, we impose the bold simplifying assumption that there is no substitution or complementarity among the installed mobile apps. Instead, we capture the substitution and complementarity between the apps installed in the first and second periods through consumer characteristics z_i, which includes information on the apps installed in the first period. Practically, this approach would help study issues related to the installation of multiple apps.

We can address the third issue of mixed business models by incorporating the average advertisement of each app in addition to the traditional "price" such as the download price and in-app purchases, into the model. In Kawaguchi et al. (2022a), the authors defined the "consumer's disutility" as the sum of the disutility of paying the money and watching the advertisement, $c_j = \alpha_e e_j + \alpha_a a_j$ and extended the traditional merger analysis based on this concept. Even if an app charges a zero download price and in-app purchases, it usually shows advertisements to earn revenue. Then, the consumer's disutility from using the app is not zero. Thus, we can apply the standard demand estimation method and merger analysis as long as the apps use either of the business models.

Based on this discussion, we model the consumer decision problem in the second period as follows: A consumer chooses mobile OS $w_i \in \mathcal{W}$ and then decides whether to install an app for each $j \in \mathcal{J}_{w_i}$. Let d_{ij} denote a variable that takes the value of 1 if consumer i installs app j in the second period and 0 otherwise. Then, the consumer's problem is:

$$\max_{d_{ij}, j \in \mathcal{J}_{w_i}} \sum_{j \in \mathcal{J}_{w_i}} d_{ij}[\beta_i' x_j - \alpha_e e_j - \alpha_a a_j + \epsilon_{ij}]$$

The decisions made to install mobile apps are mutually independent, and mobile app j is installed if and only if the following condition is satisfied:

$$\beta_i' x_j - \alpha_e e_j - \alpha_a a_j + \epsilon_{ij} \geq 0.$$

Further, assuming that ϵ_{ij} follows an independent standard logistic distribution, the probability of mobile app j being installed is

$$p_{ij}(e_j, a_j) = \frac{\exp(\beta_i' x_j - \alpha_e e_j - \alpha_a a_j)}{1 + \exp(\beta_i' x_j - \alpha_e e_j - \alpha_a a_j)}$$

and the expected indirect utility of mobile apps that can be installed after selecting w is:

$$v_{iw}(e, a) = \mathbb{E} \max_{d_{ij}, j \in \mathcal{J}_w} \sum_{j \in \mathcal{J}_w} d_{ij} u_{ij} = \sum_{j \in \mathcal{J}_w} \log\left[1 + \exp(\beta_i' x_j - \alpha_e e_j - \alpha_a a_j)\right] + \gamma \cdot |\mathcal{J}_w|$$

where γ is the Euler's constant.

Next, we consider the choice of mobile OS in the first step. We write the expected indirect utility for consumer i by choosing mobile OS w as

$$v_{iw}(e, a) + \zeta_w + \epsilon_{iw}$$

and normalizes $\zeta_{Both} = 0$, where ζ is the utility specific to each mobile OS. This utility is determined by the service provided by the mobile OS and the complementary goods and services for the mobile OS. We can, in principle, estimate the contribution of those services to ζ_w, but we would not be able to obtain a reliable estimate if there are only two OSs in the market unless we accumulate long panel data. Furthermore, assuming that ϵ_{iw} follows an independent Type-I extreme value distribution, the probability of choosing w is:

$$p_{iw}(e, a) = \frac{\exp[v_{iw}(e, a) + \zeta_w]}{\sum_{w \in \mathcal{W}} \exp[v_{iw'}(e, a) + \zeta_{w'}]},$$

By defining θ as the parameters $\beta_0, \Pi_\beta, \alpha_e, \alpha_a, \{\xi_w\}_{w \in \mathcal{W}}$, the log-likelihood of the mobile OS choice, w_i, and mobile app installation selection, $d_i = (d_{ij})_{j \in \mathcal{J}}$, by consumer

$i = 1, \cdots, N$ in the second period is

$$l(\theta) = \sum_{i=1}^{N} \sum_{w \in \mathcal{W}} \left[1\{w_i = w\} \log p_{iw}(e, a) + \sum_{j \in \mathcal{J}_w} d_{ij} \log p_{ij}(e, a) \right].$$

Parameter estimates were obtained by maximizing this likelihood.

Based on the estimated parameters, we can predict the number of installations for each app, $(s_j)_{j \in \mathcal{J}}$, and the number of mobile OSs selected, $(s_w)_{w \in \mathcal{W}}$, as a function of the download and in-app purchase price, $e = (e_j)_{j \in \mathcal{J}}$, and the ad volume, $a = (a_j)_{j \in \mathcal{J}}$, of each app, as

$$s_j(e, a) = \sum_{i=1}^{N} \sum_{w \in \{o_j, Both\}} p_{iw}(e, a) p_{ij}(e, a)$$

$$s_w(e, a) = \sum_{i=1}^{N} p_{iw}(e, a),$$

This prediction enables us to conduct a market definition and market power assessment. The relevant market definition is described in subsection 4.4, and the market power assessment is described in subsection 4.5.

4.2 The case of imperfectly competitive advertising market

Next, we consider imperfect competition in the advertising market. In this case, mobile app developers can decide on the advertisement price, and advertisers decide on the ad volume. When we study the behavior of mobile apps with a large share in the product and advertisement markets, such as Facebook, we need to consider this case. Because the model becomes complicated, it is inevitably more challenging to solve and estimate.

There are several ways to analyze the market power of mobile apps in advertising. In this study, as a relatively simple approach, we propose a discrete choice model that assumes multi-homing advertisers. It is not impossible to consider single-homing advertisers, but it requires a numerical method to solve the equilibrium and disallows us from defining the aforementioned concept of consumer disutility.

When a set of mobile apps $\mathcal{J}$ is given, the advertiser's utility for placing ads on mobile app $j \in \mathcal{J}$ is defined as

$$(b_{jl} - r_j) s_j,$$

where

$$b_{jl} = \exp\left(\gamma' x_j + \epsilon_{jl}\right),$$

is the profit advertiser l can make per consumer when ads are displayed on mobile app j, ϵ_{jl} is a profit shock, r_j is the advertisement price per ad display, and s_j is the number of users of mobile app j. If mobile app j is an app that runs on a certain mobile OS, the number of users of mobile app j is determined by the number of single-homing consumers on the OS using mobile app j and the number of multi-homing consumers using the app on the OS.

Assuming that ϵ_{jl} follows the standard normal distribution, the probability that an advertiser places an ad in app j is given by

$$a_j(r_j) = \Pr\left[\exp\left(\gamma' x_j + \epsilon_{jl}\right) > r_j\right]. = 1 - \Phi\left(\log r_j - \gamma' x_j\right)$$

where Φ denotes the cumulative distribution function of the standard normal distribution. This shows a one-to-one mapping between advertisement price r_j and ad volume a_j. If ad volume a_j is given, we can derive the consumer's choice probability of mobile app p_{ij} and that of mobile OS p_{iw} as well as the perfectly competitive case. Hence, we can write the model as a function of either r_j or a_j: To make this consistent with the notation of the perfectly competitive case, we write it as a function of a_j.

We can estimate the parameter using the maximum likelihood method and a perfectly competitive model. The difference is that we must solve the equilibrium $(s_j^*, a_j^*)_{j\in\mathcal{J}}$ for each parameter, θ. By letting $(s_j(\theta), a_j(\theta))_{j\in\mathcal{J}}$ denote the equilibrium, the probability of mobile app j to be installed is

$$p_{ij}[e_j, a_j(\theta)] = \frac{\exp[\beta_i' x_j - \alpha_e e_j - \alpha_a a_j(\theta)]}{1 + \exp[\beta_i' x_j - \alpha_e e_j - \alpha_a a_j(\theta)]},$$

expected indirect utility obtained from apps that can be installed after selecting w:

$$v_{iw}[e, a(\theta)] = \sum_{j\in\mathcal{J}_w} \log\left\{1 + \exp[\beta_i' x_j - \alpha_e e_j - \alpha_a a_j(\theta) + \epsilon_{ij}]\right\} + e \cdot |\mathcal{J}_{w_i}|,$$

and the probability of selecting the mobile OS w is

$$p_{iw}[e, a(\theta)] = \frac{\exp\{v_{iw}[e, a(\theta)] + \zeta_w\}}{\sum_{w'\in\mathcal{W}} \exp\{v_{iw'}[e, a(\theta)] + \zeta_{w'}\}}$$

The ad volume on the mobile app j is given by $a_j(\theta)$.

Given this, the log-likelihood of mobile OS choice, w_i, and mobile app choice, $d_i = (d_{ij})_{j\in\mathcal{J}}$, by consumer $i = 1, \cdots, N$ in the second period and of the ad volume on each mobile app is

$$l(\theta) = \sum_{i=1}^{N} \sum_{w\in\mathcal{W}} \left[1\{w_i = w\} \log p_{iw}[e, a(\theta)] + \sum_{j\in\mathcal{J}_w} d_{ij} \log p_{ij}[a_j(\theta), e]\right] + \sum_{w\in\{iOS, And\}} \sum_{j\in\mathcal{J}_w} \log \phi[a_j - a_j(\theta)].$$

where ϕ denotes the density function of the standard normal distribution. This assumes that the ad volume data have observation errors that obey the standard normal distribution. Parameter estimates were obtained by maximizing this likelihood.

By using the estimated parameters, we can predict the number of mobile app installations, $(s_j)_{j\in\mathcal{J}}$, the number of mobile OSs selected, $(s_w)_{w\in\mathcal{W}}$, the advertising price, $(r_j)_{j\in\mathcal{J}}$ as a function of the download and in-app purchase price, $e = (e_j)_{j\in\mathcal{J}}$, and the ad volume, $a = (a_j)_{j\in\mathcal{J}}$, as

$$s_j(e, a) = \sum_{i=1}^{N} \sum_{w\in\{o_j,Both\}} p_{iw}(e, a)p_{ij}(e, a),$$

$$s_w(e, a) = \sum_{i=1}^{N} p_{iw}(e, a),$$

$$r_j(a_j) = \exp[\Psi^{-1}(1 - a_j) + \gamma' x_j],$$

This prediction can be used to conduct market definitions and market power assessments.

4.3 Extensions

Thus far, the specification does not include a random effect in β_i; extending the model by including a random effect is easy. However, this increases the computational burden and destabilizes the mobile app's equilibrium price and ad volume computation. In addition, the unique consumer's disutility is no longer defined once we consider a random coefficient for the disutility of losing money α_e and the disutility of watching advertisements α_a because disutility becomes heterogeneous across consumers. We did not consider endogeneity between the mobile app's price, ad volume, and unobserved fixed effects. This can be addressed by using the control function approach (Petrin and Train, 2010).

Thus far, the discussion has assumed that the mobile app choice after the mobile OS choice is independent. If we only consider substitutability and complementarity among specific apps, we can handle them without complicating the model. For example, suppose that app $j = 1$ offered in iOS and app $j = J$ offered in Android are the same for each mobile OS. Multihoming consumers may not want to install app $j = J$ if they install app $j = 1$. This could happen if the app is a game app because the apps are substitutes; similarly, they may want to install app $j = J$ more if they install app $j = 1$. This could happen if the app is a productivity app because the apps are likely to complement them.

In this case, we can assume that the multihoming consumer faces the following problem: Let m_i be a variable of the consumer's selection of $\{No, 1, J, Both\}$, consider

$$\max_{b_i,d_{ij},j\neq 1,J\in\mathcal{J}_{Both}} \sum_{j\neq 1,J\in\mathcal{J}_{w_i}} d_{ij}[\beta_i' x_j - \alpha_e e_j - \alpha_a a_j + \epsilon_{ij}] + \sum_{b\in\{No,1,J,Both\}} 1\{b_i = b\}(v_{ib} + \epsilon_{ib}),$$

$$v_{i,No} = 0,$$

$$v_{i1} = \beta_i' x_1 - \alpha_e e_1 - \alpha_a a_1,$$

$$v_{iJ} = \beta_i' x_J - \alpha_e e_J - \alpha_a a_J,$$

$$v_{i,Both} = \sum_{j=1,J} (\beta_i' x_j - \alpha_e e_j - \alpha_a a_j) + \Delta_{1j},$$

That is, we consider a combinatorial discrete choice problem that allows complementarity ($\Delta_{1J} > 0$) and substitutability ($\Delta_{1J} < 0$) for these two mobile applications only.

Assuming that mobile apps other than $j = 1, J$ have no influence and ϵ_{ib} follows the Type-I extreme value distribution, the probability of mobile apps $1, J$ being installed is

$$p_{ib}(e_1, e_J, a_1, a_J) = \frac{\exp(v_{ib})}{\sum_{b' \in \{No,1,J,Both\}} \exp(v_{ib'})}$$

and the expected indirect utility obtained from the apps that can be installed is

$$v_{i,Both}(e,a) = \sum_{j \neq 1,J, \in \mathcal{J}_{Both}} \log\left[1 + \exp(\beta_i' x_j - \alpha_e e_j - \alpha_a a_j + \epsilon_{ij})\right] + \log\left[\sum_{b' \in \{No,1,J,Both\}} \exp(v_{ib'})\right] + e \cdot (|\mathcal{J}_{Both}| - 1)$$

The above expression is slightly complicated, but there is no major difference from previous models.

It is worth noting that this framework applies to competition with adjacent markets such as web apps and console games. In other words, we must only consider a model that extends the device/OS choice $\mathcal{W}$ from $\{iOS, Android, Both\}$ to $\{iOS, Android, PlayStation, iOS\&Android, Android\&PlayStation, All\}$. It is advisable to assume that web apps can be installed under an arbitrary mobile OS choice w. The main issue here is data, not modeling. We need data on i) devices owned ($\{iOS, Android, PlayStation, iOS\&Android, Android\&PlayStation, All\}$) and ii) services used at the consumer year level, and data on i) purchase prices, ii) average in-app purchases, and ii) average ad volume at the year level.

4.4 Market definition

We can conduct a hypothetical monopolist test based on the concept of a "Small but Significant and Non-transitory Increase in Price (SSNIP)" even in the app market. Specifically, let us consider how to test whether "all iOS apps constitute a single antitrust market". To do so, we consider a hypothetical monopolist who retains the rights to all iOS apps, $\mathcal{J}_{iOS}$. The profits (sales) of the hypothetical monopolist under an observed download and in-app purchase price, e, and ad volume, a, are

$$\pi_{iOS}(e,a) = \sum_{j \in \mathcal{J}_{iOS}} (e_j + r_j a_j) s_j(e,a).$$

We then consider an SSNIP, say, a 5% increase in price, as well as the standard SSNIP test. The problem is that the hypothetical monopolist can either increase the download and in-app purchase prices by 5% or increase the ad volume by 5%. We propose two approaches to solve this problem.

The first approach is to judge that it constitutes the antitrust market if the hypothetical monopolist can profitably raise either the download or in-app purchase price or the ad volume by 5%. This is because the hypothetical monopolist could increase the profit by more efficiently combining the increase in the download and in-app purchase price and ad volume. Specifically, let e' denote the price vector when there is a 5% increase in the download and in-app purchase prices, and a' denote the ad vector when the ad volume is increased by 5%, if either of the conditions

$$\pi_{iOS}(e',a) > \pi_{iOS}(e,a),$$

or

$$\pi_{iOS}(e,a') > \pi_{iOS}(e,a)$$

is met, we judge that the iOS apps constitute a single antitrust market.

This is a conservative way of defining a market: if the hypothetical monopolist can increase the profit by this, then the market is certainly defined as such; however, even if the hypothetical monopolist cannot increase the profit by this, it is not necessarily true that the market is not defined.

We can follow the same procedure to define the market, even if competition in the advertising market is imperfect. In this case, it should be noted that advertisement price r is a function of ad volume a. The profit of the hypothetical monopolist under the observed download, in-app purchase price e, and ad volume a is

$$\pi_{iOS}(e,a) = \sum_{j \in \mathcal{J}_{iOS}} [e_j + r_j(a_j) a_j] s_j(e,a),$$

and we judge that iOS apps constitute an antitrust market if either of the conditions

$$\pi_{iOS}(e',a) > \pi_{iOS}(e,a),$$

or

$$\pi_{iOS}(e,a') > \pi_{iOS}(e,a)$$

is met.

The second approach rigorously defines the antitrust market by using the concept of consumer disutility. The consumer's disutility from using app j is defined by the difference in the indirect utility between when the mobile app's download and the in-app purchase price is 0 and ad volume is 0; when they are e_j and a_j, that is, $c_j = \alpha_e e_j + \alpha_a a_j$.

The consumer model indicates that $c = (c_j)_{j \in \mathcal{J}}$ is a sufficient statistic of download and in-app purchase price and ad volume in both mobile app choice probability p_{ij} and mobile OS choice probability p_{iw}.

$$p_{ij}(c_j) = \frac{\exp(\beta_i' x_j - c_j)}{1 + \exp(\beta_i' x_j - c_j)}$$

$$v_{iw}(c) = \mathbb{E} \max_{d_{ij}, j \in \mathcal{J}_w} \sum_{j \in \mathcal{J}_w} d_{ij} u_{ij} = \sum_{j \in \mathcal{J}_w} \log\left[1 + \exp(\beta_i' x_j - c_j)\right] + e \cdot |\mathcal{J}_w|$$

$$p_{iw}(c) = \frac{\exp[v_{iw}(c) + \zeta_w]}{\sum_{w \in \mathcal{W}} \exp[v_{iw'}(c) + \zeta_{w'}]}$$

This means that the interaction between a mobile app and a consumer and between mobile apps matters only through the consumer's disutility c. Therefore, conditional on consumer disutility c, the optimal download, in-app purchase price, and ad volume are determined independently across mobile apps.

We define the profit of the mobile device under the optimal download, in-app purchase price, and ad volume as:

$$\pi_j^*(c) = \max_{e_j, a_j : \alpha_e e_j + \alpha_a a_j = c_j} (e_j + r_j a_j) s_j(c)$$

or

$$\pi_j^*(c) = \max_{e_j, a_j : \alpha_e e_j + \alpha_a a_j = c_j} [e_j + r_j(a_j) a_j] s_j(c)$$

Then, the profit of the hypothetical monopolist who retains the rights to all iOS apps under consumer disutility c is

$$\pi_{iOS}^*(c) = \sum_{j \in \mathcal{J}_{iOS}} \pi_j^*(c)$$

By letting c' denote the vector of consumers' disutility when it is raised by 5%, we judge that iOS apps constitute an antitrust market if the condition

$$\pi_{iOS}^*(c') > \pi_{iOS}^*(c)$$

is met.

This method determines a conceptually correct antitrust market under the current modeling assumption. However, the result that the consumer's disutility is uniquely determined and works as a sufficient statistic for the interaction across players depends on several modeling assumptions. If we consider a more complicated setting, it is advisable to try the first approach, which does not rely on well-defined consumer disutility.

This framework can be applied to an arbitrary set of mobile applications. For example, if we consider all iOS and Android game apps, we can consider a hypothetical monopolist for those apps and apply the aforementioned framework. If we consider all mobile game apps and console games, after estimating demand by incorporating game consoles into the platform choice, we can use the same test.

4.5 Assessment of market power

Using this model to express consumer demand, advertiser demand, and profits of mobile app developers as a function of consumer disutility, we can also define standard indicators for assessing market power, such as elasticity, conversion ratio, and upward pricing pressure.

For example, the consumer disutility elasticity of a mobile app can be calculated as follows:

$$\eta_j^s = \frac{\partial \ln s_j(c)}{\partial \ln c_j}$$

If the advertising market is assumed to be in perfect competition, we can use it as an indicator of the mobile app's market power. If the advertising market is in imperfect competition, then in addition to this, the own advertisement price elasticity:

$$\eta_j^a = \frac{\partial \ln a_j(r_j)}{\partial \ln r_j}$$

also need to be considered.

First, we explain why own-price elasticity is an indicator of market power. Let us imagine firm j which sells a product with marginal cost mc_j at price e_j. If the demand for the product is $s_j(e_j)$, the profit is $\pi_j(e_j) = (e_j - mc_j) \times s_j(e_j)$. The first-order condition of profit maximization for e_j is:

$$\frac{\partial \pi_j(e_j)}{\partial e_j} = s_j(e_j) + \frac{\partial s_j(e_j)}{\partial e_j}(e_j - mc_j) = 0$$

Rearranging this gives the Lerner index:

$$\frac{e_j - mc_j}{e_j} = \frac{1}{\eta_j^s}$$

The left-hand side of the equation is the markup rate, and the right-hand side is the reciprocal of the price elasticity of demand. From this equation, the lower the own-price elasticity, the higher the markup rate. Therefore, own-price elasticity is used as a (reverse) indicator of market power.

Similarly, the advertising elasticity of consumer demand and the advertising price elasticity of ad demand can be used as indicators of market power for the following reasons. If we consider a situation in which the developer of a paid mobile app j sets the ad volume a_j and charges price e_j, the first-order condition of profit maximization for price e_j is:

$$\alpha_y \frac{\partial s_j}{\partial c_j} \pi_j^*(c_j) + s_j = 0.$$

Rearranging this gives the profit per download $\pi_j^*(c_j)$ as

$$\frac{\pi_j^*(c_j)}{c_j} = \frac{1}{\alpha_y \eta_j^s}$$

where

$$\frac{\pi_j^*(c_j)}{c_j}$$

is the markup rate generalized to situations where the app has multiple ways of earning revenue.

The first-order condition for the ad volume a_j is:

$$\alpha_a \frac{\partial s_j}{\partial c_j} \pi_j^*(c_j) + s_j \left(r_j'(a_j) a_j + r_j(a_j) \right) = 0,$$

and rearranging this yields:

$$\frac{\pi_j^*(c_j)}{c_j} = \frac{r_j \left(1 + \frac{1}{\eta_j^a}\right)}{\alpha_a \eta_j^s}.$$

From the formula above, the higher the advertising rate and the lower the price elasticity of ad demand, the higher the generalized markup rate. Furthermore, as we rewrite the equation for the advertisement price r_j, we obtain

$$r_j = \frac{\pi_j^*(c_j)}{c_j} \frac{\alpha_a \eta_j^s}{1 + \frac{1}{\eta_j^a}},$$

This formula tells us that the higher the advertising price elasticity of ad demand, the lower the advertising rate tends to become, and the larger the ad volume tends to become. The higher the disutility elasticity of consumer demand, the higher the advertisement price tends to become, and the lower the ad volume tends to become.

In this example, although the first-order conditions of optimization and the own price elasticity to be evaluated for paid apps are different from those to be evaluated for free apps, the market power of a mobile app can be uniformly assessed from the estimate of the same model.

If we want to calculate the conversion ratio between the mobile app j of mobile app developer d and a mobile app of another mobile app developer d, let $\mathcal{J}_d$ denote apps owned by developer d, $s_d(c_d) = (S_j(c_j))_{j\in\mathcal{J}_d}$, which can be calculated by

$$\left(\frac{\partial s_d(c_d)'}{\partial c_j}\right)^{-1}\left(\frac{\partial s_{d'}(c_{d'})'}{\partial c_j}\right).$$

The upward pricing pressure of app j is defined as the difference between the first-order condition before and after the merger (Jaffe and Weyl, 2013), that is,

$$-\left(\frac{\partial s_d(c_d)'}{\partial c_j}\right)^{-1}\left(\frac{\partial s_{d'}(c_{d'})'}{\partial c_j}\right)\pi_{d'}(\delta_{d'}),$$

Rigorous assessment of market power requires counterfactual analyses, such as merger simulation, but such analyses require cost-related parameters on the supply side (e.g., mobile app developers). In addition, the calculation of download and in-app purchase price e and ad volume a in the equilibrium generally requires a substantial amount of time. Kawaguchi et al. (2022a) estimated cost-related parameters at the supply side and performed a series of counterfactual analyses using a similar model, but it may not be realistic to conduct such in-depth analyses in policy analysis.

5 Concluding Remark

This study discusses a method to define the antitrust market and evaluate the market power of mobile apps. Finally, we describe issues that we could not address in this study.

The empirical method of this study focused on the analysis of consumers and advertisers and took the behavior of mobile app developers as given. Nevertheless, to evaluate the platform firm's market power and anti-competitive behavior, we would have to endogenize the app developer's behavior and evaluate their response to the increase in app store fees and mobile device prices. This type of analysis requires more developer data. In addition, we treated payment services as exogenous adjacent markets. However, in some cases, such adjacent markets may have to be handled explicitly as markets for payment method service providers. Thus, we need extra data on the payment method usage outside app stores.

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