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On the economics of the Android case

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ABSTRACT
We provide an economic rationalization for concerns that restrictions in the contracts between Google and manufacturers of mobile devices based on the Android operating system have anti-competitive effects. We extend recent insights on tying in two-sided markets (by Choi and Jeon), showing that tying of Google's app store with its search app (and revenue sharing agreements which compensate manufacturers for exclusivity) can protect and increase Google's profits from search advertising, and help it outbid or marginalize other search engines. Two-sidedness with some pricing constraint on the Google suite can "break" the "One Monopoly Profit" paradigm – even with linear pricing for the Google Suite under heterogeneous consumers. While it is not possible for Google to extract all consumer surplus from the app store as a standalone product, part of this surplus can be extracted through the tying strategy, which shifts additional profits towards the dominant firm and reduces consumer welfare.

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A. Introduction

The "Android case", at time of writing still pending before the European Commission and other authorities (but concluded with an infringement decision by the Russian Federal Antimonopoly Service), has attracted considerable interest in antitrust circles, both from a legal and an economic perspective.[1] In this article, we put forward an economic interpretation of the

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[1]For a legal analysis see, for instance, Benjamin Edelman and Damien Geradin, 'Android and Competition Law: Exploring and Assessing Google's Practices in Mobile' (2016) 12(2-3) European Competition Journal 159. For an economic analysis see, in particular, Jay Pil Choi and Doh-Shin Jeon, 'A Leverage Theory of Tying in Two-Sided Markets' (2016) CEPR Discussion Paper 11484, which is closely related to earlier work by Andrea Amelio and Bruno Jullien, 'Tying and Freebies in Two-sided Markets' (2012) 30 International Journal of Industrial Organization 436.

anti-competitive mechanisms at play, based on modern theories of anti-competitive tying, and we offer a new perspective based on an extension of recent important work by Choi and Jeon.[2]

The premise for our analysis are certain features of the contractual agreements that Google enters into with original equipment manufacturers (OEMs) that produce mobile devices with an Android operating system: namely, the "Mobile Application Distribution Agreements" (MADAs), the Revenue Sharing Agreements (RSAs) and the Anti-Fragmentation Agreements (AFAs). Taken together, these agreements de facto allow Google to tie its app store "Google Play" with its search engine Google Search, giving OEMs financial incentives to pre-install them on their devices, with the effect of foreclosing rivals and protecting Google's dominance in search advertising. In particular, we show how the use of these agreements by Google can be motivated as a means to ensure exclusive pre-installation of its search engine application as the default search engine on Android devices, and foreclose installation of rival search engine providers, as well as the growth of OEMs producing the so-called "forked" Android devices (i.e. devices using the Android OS without Google Play and other key apps by Google) – in a way that reduces both consumer surplus and welfare to its own advantage.

The article is organized as follows. Section B provides a stylized overview of some key features of the case, setting the stage for the subsequent economic analysis. Section C evaluates the extent to which traditional theories of anti-competitive tying (e.g. Whinston and others[3]) hold in this case, and highlights, in particular, a recent analysis by Choi and Jeon that is especially relevant because it explicitly focuses on a two-sided setting – which is appropriate for application stores and search engines.[4] Choi and Jeon (explicitly with the Android case in mind) show that a dominant firm in a two-sided primary market can tie its primary good with a secondary good produced in a competitive two-sided market, and deter entry in the latter in a profitable way, as long as there are some constraints on the prices it can charge on the consumers' side. We argue that these models are useful and relevant to evaluate anti-competitive tying, but they do not quite capture in full all important features of the Android case.

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[2]Choi and Jeon (n1).

[3]See Michael D. Whinston, 'Tying, Foreclosure, and Exclusion' (1990) 80(4) American Economic Review 837; Dennis W. Carlton and Michael Waldman, 'The Strategic Use of Tying to Preserve and Create Market Power in Evolving Industries' (2002) 33(2) RAND Journal of Economics 194.

[4]Choi and Jeon, *supra* (n 2).

Section D sets out an extension of the Choi and Jeon model, that seeks to reflect more closely the salient features of the case (formal details can be found in the final Appendix). We assume that both Google and a "more efficient" search engine can pay OEMs to pre-install their search apps, but Google cannot fully extract the entire surplus that consumers obtain from its application store and other apps as a standalone product – either because of the initial commitment to zero price, or because consumers have heterogeneous preferences and even optimal pricing cannot extract all consumer rents in full. In such cases, tying is attractive to Google because it improves profits – either by outbidding the rival search engine for pre-installation of the search app with full foreclosure; or (when preferences are heterogeneous) by attracting consumers with the highest valuation of its application store and marginalizing the rival search engine on forked devices. We show that, under weak conditions, tying is profitable and reduces consumer surplus by forcing all or most consumers to use expensive devices with an inferior search app.

In Section E, we review complementary motivations behind the conduct at issue: in particular, we discuss how RSAs with selected OEMs can generate a typical mechanism of "naked exclusion"[5] which reinforces our main argument. In practice, Google can pay selected OEMs in a separate or sequential way to reach exclusivity and, at the same time, limit the amount of payments through a "divide-and-conquer" strategy. Section F focuses on remedies and provides some conclusions.

B. Antitrust concerns in the supply of Android devices

Android smartphones accounted in 2016 for about 70–80% of all smartphones sold in Europe, and for over 80% of worldwide smartphone sales. The share of Apple iOS in all smartphone sales is slightly above 10%, while that of Windows Phone and other operating systems is negligible.[6] As Apple's iOS is non-licensable to OEMs, Android is by far the dominant system in the supply of licensable OSs.

Until recently OEMs could choose from a variety of proprietary OSs, including Symbian and Windows Phone, and a variety of open source alternatives. Google developed its successful Android environment, launched in 2007, and this rapidly conquered the market thanks to its

[5]The classic argument on naked exclusion comes from Eric B. Rasmusen, J. Mark Ramseyer and John S. Wiley Jr., 'Naked Exclusion' (1991) 81(5) American Economic Review 1137.

[6]Estimates from various sources that are publically available.

free distribution model as an open source OS, and the development of a wide range of applications. Note that while at the retail level Android devices compete with Apple devices, in practice only few Android devices directly compete with the iPhone in the high price segment.[7] This limits the "indirect constraint" that be argued to bear on the Android OS as a result of competition with Apple devices downstream. Moreover, as the Apple iOS is non-licensable, OEMs seeking to "kit out" a phone can only choose in practice between Android, Windows Mobile (in decline over the last few years) and marginal players.[8]

Google also supplies its Google Mobile Service (GMS) suite for Android devices, which mainly includes the application store GooglePlay (since 2008, replacing Android Market) working with GooglePlay Services (GPS), which is a software component that ensures that apps using Google APIs are properly communicating with Google online services. In this article, we will refer to this software package as the "GP/GPS suite". Google provides this suite only through pre-installation and free of charge to any OEM that signs MADA and AFA.

As well known, a software platform is a two-sided market where revenues can be realized either on the buyers' side, here the OEMs, or on the sellers' side, here application developers and advertisers. Google monetizes its GP/GPS suite and its main applications (such as YouTube or Chrome) only on one side. That is, Google does not charge directly OEMs for adopting the GP/GPS suite,[9] but monetizes its value through application developers and advertisers: it receives a fixed percentage of revenues from application developers, and additional revenues from in-app advertising powered by Google products, promoting the Google "ecosystem" which generates most of its revenues through online search advertising. The same can be said of an application without effective substitutes such as Youtube, which obtains revenues through advertising, and Chrome, which is also monetized through search advertising powered by Google Search.

[7]The average selling price of iOS smartphones worldwide was 59% higher than the average price of Android smartphones in 2010, 159% higher in 2014 and 221% higher in the first quarter of 2016. Source: CRA based on data from Statista.com and Fortune.

[8]In any case, even taking retail competition into account, Google would gain from foreclosing rival search engines within the Android environment as long as its search revenues more than compensate other lost revenues from reduced sales of Android devices; moreover, higher Android costs would soften price competition in the retail duopoly with Apple and would increase the incentives of Google to pay for exclusivity of Google Search on iPhone, which de facto neutralizes the competitive effects of retail competition.

[9]Nevertheless, the imposition of strong requirements on OEMs, in particular of the default position of Google Search, represents an opportunity cost that OEMs have to bear to obtain GP/GPS.

This business model has been crucial for Google to attract OEMs and final consumers on the Android ecosystem, and a huge number of application developers to the GP application store. The open source nature of Android and the free provision of a high-quality application store, plus some unique applications, have been crucial for the success of Google in the market for mobile OSs and application stores. Having reached dominance in this space, Google can exploit it to protect its core business of search advertising on both mobiles and fixed devices, where it obtains most of its profits.

To produce a "normal" Google Android device (one with the GP/GPS suite provided for free by Google) OEMs need to sign MADAs which involve a number of restrictions on the applications that can be pre-installed on their mobile devices. Notice that the role of pre-installed applications is crucial in mobile because most online traffic originates from access through these dedicated applications, due to both an easier user experience and a technological advantage compared with traditional access through Internet navigation. This "default bias" is well known in the literature, and features in the decisional practice of the European Commission with reference to Internet Explorer as the default browser on PCs, and with reference to Safari as the default browser on Apple devices.

In particular, MADAs appear to imply two main requirements. First, OEMs should *pre-install* certain applications (for instance, YouTube, GoogleMaps, Chrome, Google Search and others, as specified by Google) on the device and display them in a prominent position (such as on the default home screen or in the next panel). Many Google applications are of course extremely valuable to consumers; and some have no real substitutes of comparable quality.[10] GooglePlay, in particular, is by far the richest application store for Android devices (alternatives such as Amazon AppStore, Yandex Store, Samsung's Galaxy Apps, Opera Mobile Store and others have far fewer applications) and the only one that provides most Google applications and automatic updates: the quality difference, as perceived by consumers, between GooglePlay and any other alternative application store is substantial. Other applications have a variety of substitutes of different quality levels (for instance, GoogleMaps or Google Search).

Typically, MADAs require also that Google Search is set *as the default search provider*, and as the default search engine for the voice search

[10]On this and, specifically, on the dominance of Google Play in the market for application stores for Android devices see Edelman and Geradin, *supra* (n 1).

function, the hardware-button-activated search function and other advanced options in recent smartphones. The same occurs for the browser, Chrome, which in turn has incorporated Google Search as default search engine and is a main access to search for most users. These requirements contribute to providing a common user experience based on Google products on all normal Android devices, but they also limit the ability of OEMs to mix and match applications according to market demand, and reduce opportunities for product differentiation. Tying of Google Search with the GP/GPS suite started in 2009.

Note that signing MADAs does *not* explicitly prevent OEMs from pre-installing other applications competing with those of Google, or even other search engines. However, the incentive to pre-install duplicate applications is constrained by the limited screen space available on devices. Even if rival applications are pre-installed, they cannot obtain *exclusive* pre-installation and they cannot be given the same prominent position as the Google applications. Most importantly, in the case of search engines, the concern is that the only possible pre-installation is without a prominent position and without the default status. The implication is that while some users may still download applications that do not come pre-installed, in practice this happens rarely unless there is a large difference in quality compared pre-installed applications; and even downloading an alternative browser and an alternative search engine would not bypass the default status of Google Search. This can reduce the chance of other search engines being used, if the tendency to use the most prominently placed browser, Chrome, which has Google Search as its default, or the most prominently placed search widget, which is also based on Google Search by default, is indeed pervasive for a large proportion of end-users.

A second set of restrictions is contained in the AFAs. Their objective is ostensibly to prevent OEMs that produce normal Google Android devices from modifying the Android code into what is usually known as a "fork", as this could undermine compatibility with Google applications. While this contributes to homogenizing user experiences on normal Android devices, it is not clear how the existence of alternative devices with a different user experience could harm consumers and therefore how such limitations could be in the interest of consumers. In any case, the absence of clear and objective criteria for AFAs and for certification by Google can limit access to other innovative technologies based on the Android open source system and limit product differentiation and competition between differentiated OSs. As AFAs apply at company level, and, therefore, to all devices produced by an OEM for different markets and in different periods, they restrict the ability of OEMs to diversify their range with both normal and forked Android devices, and to gain experience in the production of forked Android devices. This leaves attempts in this direction mainly to companies that never produced Android devices (as Nokia did in 2014 with the Nokia X) or new to mobile devices altogether (Amazon in 2014 with the Fire Phone), whose chances of success are much lower in an industry where network effects and learning by doing are key factors.

On top of MADAs and AFAs, Google also offers RSAs to a selected group of major OEMs of Android-based devices and mobile network operators (MNOs), in exchange for exclusivity.[11] RSAs prevent them from pre-installing competing search engines anywhere on their devices. These agreements could be based on exclusive pre-installation on a portfolio of products or on precise devices, but, in either case, they make it attractive for OEMs to pre-install Google Search as the only search engine in any entry point on all their devices.[12] Similar agreements have been reached with Apple: in 2014 Google was estimated to have paid $1 billion to Apple to be the only default search engine on iPhones and iPads.[13]

The role of RSAs for Android devices is not immediately obvious. If Google has already obtained through MADAs pre-installation in a prominent position of Chrome and of Google Search as the default search engine, RSAs can only prevent OEMs from obtaining duplicative pre-installation of other search engines in a non-prominent position (or in browsers different from Chrome that are pre-installed in a non-prominent position). These exclusivity provisions may exert a limited incremental foreclosure effect compared to the default status already reached by Google through the MADAs. Therefore, to understand their role in a potential foreclosure strategy it would be important to understand if and how Google has the ability and the incentive to use these RSAs to outbid rival search engines, foreclose their entry and ultimately to harm

[11]The distinction between OEMs and MNOs is not relevant for our discussion, but we should mention that MNOs obtain a larger benefit from these agreements because they can also exploit their own app stores and obtain revenue sharing agreements also from devices running on other OSs, including Windows Phone and iOS.

[12]Device-based agreements have a fidelity-enhancing purpose which can be less restrictive from a legal point of view than portfolio-based agreements, but the impact is substantially the same from an economic point of view.

[13]Exclusivity agreements have also concerned browsers: in 2010, it was estimated that Google contributed 85% of Mozilla's $123m revenue through an agreement to pre-install search on Mozilla's Firefox browser. This allows Google Search to be the default search engine on the large majority of browsers (with the exception of IE, which has Bing as default). Source: Searchenginewatch.com.

consumers. In this article, we provide a rationale for such a role of RSAs in an anti-competitive strategy.

The combined effect of this suite of exclusivity agreements is to reduce the ability of consumers to use and experiment with different search engines. Consumers of course still have access to other search engines through Internet navigation or by downloading apps, but switching costs and various conditions imposed by Google reduce the propensity to switch and can reinforce the position of the default search engine.

The viability of Android devices without the GP/GPS suite (and therefore not subject to MADAs and AFAs) is a key issue for the case. These forked or "bare" Android devices represent a marginal part of the market for smart phones in Europe and the rest of the world with the exception of China, where repeated interference from the Chinese government has meant a variety of alternative Android systems have developed on the basis of local app stores and applications. A "bare" Android device essentially replaces the GP/GPS suite with an alternative package of application programming interfaces and a different application store. In particular, it cannot include applications that are only available on normal Android devices, such as GooglePlay or YouTube, and this limits the quality experience that forked devices can provide to consumers relative to normal Android devices, because most Android applications are supplied through GooglePlay and only a smaller number of applications are distributed through alternative application stores. Most Android applications also only work well if they have access to GooglePlay Services. Users of bare Android mobiles miss out on the quality of these applications. Nevertheless, for some of the other Google applications, there are substitutes available, such as YahooMaps for GoogleMaps or Bing for Google Search, and they are typically pre-installed by OEMs on their forked Android devices.

A discussion of the largely failed attempts at commercializing forked Android mobiles has been put forward elsewhere in this *Journal*,[14] focusing on companies that were new to the Android environment, new to mobile production or even new to hardware production – because, as mentioned, AFAs preclude normal Android producers from switching to bare Android devices. Moreover, when companies subject to AFAs tried to commercialize Android forks, as Acer did in 2012 with Alibaba's Aliyun OS, they had to withdraw from the project if they wanted to

[14] Edelman and Geradin, *supra* (n 1). Of course, these smartphones have pre-installed applications that were not from Google: for instance, Amazon used the Amazon AppStore, Silk, which is the browser of Amazon, and Bing, which is the search engine of Microsoft.

continue producing normal Android devices. Without the panoply of contractual restrictions Google has put in place with OEMs, we may have seen the development of Android devices based on a forked Android OS, with "normal" Android devices sold at higher prices than forked Android devices. Forked devices could pre-install some applications that are alternative to Google applications, providing differentiated products at lower prices. This development has been stalled so far, to the extent that leading OEMs have been prevented from producing such devices by their exclusivity agreements with Google.

The question for the antitrust case is whether these restrictions have the effect of foreclosing and raising the costs of rivals in the supply of alternative apps, and more generally stall competition and innovation in the industry. In the rest of this paper, we discuss the economic underpinning for such a case.

C. "Old" Theories of tying and the Choi and Jeon model

There is an extensive literature on how tying can be used to deter entry, and many of its insights apply directly to the Android case. A classic analysis is that of Whinston,[15] which tells us that tying a primary product supplied by a monopolist (here Google, as a dominant provider of the GP/GPS suite) with a secondary product (here its search engine) can be an aggressive strategy used to foreclose entry in the secondary market.

Applied to the Android case, the Whinston argument would imply that bundling strengthens competition between search engines, either on the side of the payments to OEMs or on the side of advertising revenues. Given the high fixed costs involved in developing a search engine and reaching a viable scale in search, bundling that reduces the profits of an entrant can deter its entry and allow Google to extend its market power to mobile search. It is certainly plausible that tying Google Search to GP/GPS will intensify competition with rival search engines for pre-installation by OEMs and, potentially, also on the advertising side. It is also the case that there are relevant fixed costs of entry for a search engine service and therefore the entry-deterring purpose can be relevant here. Nevertheless, Whinston's analysis does not incorporate explicitly the two-sided nature of both application stores and search engines; it does not consider the possibility that other firms could produce alternative primary products

[15]See *supra* (n 2).

(application stores) that can be combined with rival search engines;[16] and does not consider explicit constraints on the price of the primary product (such as the commitment of Google to distribute GP for free).

Well-established economic models by Carlton and Waldman and Choi and Stefanadis[17] have analysed how tying can be used against the threat of entry in both the primary and secondary market, and can be employed as a foundation for a better "fitting" theory of harm in the Android case. In the spirit of Carlton and Waldman, as long as Google's rivals can only compete against its bundle by providing both an application store and a search engine pre-installed as default, Google's conduct makes it harder for third party suppliers to offer such an alternative package on Android-based devices, or at least it increases their costs and degrades the quality of their offers.[18] The argument of Choi and Stefanadis applies when primary and secondary products are complement and is particularly relevant for the Android case. In their approach, bundling reduces the incentives to invest in the development of a better application store and a better search engine because each innovation will be profitable (against the bundle) only if also the other will be successful (otherwise buyers would use the bundle).

These developments in the analysis are important because there have been attempts to develop bundles of application stores and search engines (for instance, in Russia by Yandex), and some OEMs have indeed tried to develop forked Android devices based on combinations of different applications stores and search engines (for instance, this is the case of Amazon and Nokia employing Bing as a search engine). By developing a high-quality application store and committing to distribute it for free to OEMs if bundled with Google Search, Google has attracted more applications than any other app store, and has increased the endogenous R&D cost that any potential entrant has to face to build a competitive package including an alternative app store and a search engine. If entry costs are high enough, this can be sufficient to deter entry.

[16]For alternative theories of anti-competitive tying based on the Whinston argument and that can be relevant in the case see also Barry Nalebuff, 'Bundling as a Barrier to Entry' (2004) 119 Quarterly Journal of Economics 159; and Martin Peitz, 'Bundling may Blockade Entry' (2008) 27 International Journal of Industrial Organization 41.

[17]See Carlton and Waldman, *supra* (n 2), and Jay Pil Choi and Christodoulos Stefanadis, 'Tying, Investment, and the Dynamic Leverage Theory' (2001) 32(1) RAND Journal of Economics 52.

[18]In this case there are interesting aspects of vertical contracts aimed at raising rivals' cost in the spirit of Steven Salop and David Scheffman, 'Raising Rivals' Costs' (1983) 73(2) American Economic Review 267. However, the interpretation of foreclosure in terms of exclusionary tying will be our focus in what follows.

What these models do not incorporate, however, are the specificities of search engines and application stores as two-sided markets – where providers are potentially able to monetize their services by charging either advertisers and application developers, or consumers and OEMs. A recent paper by Choi and Jeon, building on Amelio and Jullien,[19] takes this additional step and puts forward a theoretical model of anti-competitive tying in two-sided markets, explicitly referring to the Android case. In the rest of this section, we provide a brief overview of this work, setting the stage for our subsequent extension.

Choi and Jeon show that a dominant firm in a two-sided primary market can tie its primary good with a secondary good produced in a competitive two-sided market, and deter entry in the latter in a profitable way, as long as there are some constraints on the prices that can be charged. The contribution of Choi and Jeon is the first in the literature to clearly emphasize the relevance of two key elements for entry deterrence to occur: (i) the two-sidedness of the market for search engines and (ii) the existence of constraints on the payments that can be made to attract consumers.

Choi and Jeon start by showing that, if a new superior search engine could subsidize consumers to use its product and finance this through the rents obtained on the advertising side, entry can be successful and challenge the dominance of Google: this benchmark reproduces a version of the One Monopoly Profit Theorem. However, when the subsidies to consumers are not feasible, for instance, because consumers cannot be directly paid for installing applications (otherwise they would free ride and install applications they do not use), Google has an easy way to tie Google Search with the GP/GPS suite and attract consumers with a low-enough price for the bundle. The intuition is that, without tying, the price constraint softens competition, increasing the rents of the rival search engine that can be extracted by the incumbent, and at the same time, under tying, the price constraint makes it harder for the rival search engine to compete against Google. In Choi and Jeon, this simple argument rationalizes the abusive conduct of Google in the Android case.

The Choi and Jeon model is important in providing a new and general tool to analyse tying cases in two-sided markets: the *role of price*

[19] Choi and Jeon, *supra* (n 2). The first analysis of tying in two-sided markets with non-negative price constraints is actually in Amelio and Jullien, *supra* (n 1). However, the focus of this earlier research is on how a monopolistic platform can exploit tying to subsidize the constrained side and increase its profits as well as on how tying can be used strategically in a duopolistic framework (without analysing entry deterrence purposes).

constraints for the profitability of the tying strategy. However, the original specification has two main limitations when applied to the Android case:

- The first is its main assumption that firms cannot pay buyers to adopt their secondary product: while this is realistic when considering consumers (as it is unusual for search engines to pay consumers to use or install them), it is less realistic for *OEMs*. The model assumes implicitly that search engines cannot pay *OEMs* to have the search engine pre-installed on their mobile devices. But payments for pre-installation and for default position *do* actually take place in the market, and certainly Google makes such payments to *OEMs*. And because the default bias seems to be strong (most consumers use applications that are pre-installed on their mobile devices, especially if they are in a prominent and default position) rival search engines could also gain from pre-installation or exclusivity and could have incentives to pay *OEMs* for this.
- The second limitation when applying Choi and Jeon to the case at hand is that while the analysis finds that foreclosure is profitable and reduces total welfare, it also finds that consumer surplus is actually increased by tying. This happens because without tying competition is reduced, as search engines cannot subsidize adoption, while under tying competition is increased, and both the price of mobile devices and their price–quality ratio decrease, making consumers better off.

In the next section, we propose an extension of the Choi and Jeon model that appears to match the facts of the case more closely, and provide a coherent theory of harm which is not subject to the above limitations. The argument extends the principle relied upon by Choi and Jeon, for which tying can be profitable if there is some constraint on the pricing of the primary good as a standalone product, to a more realistic set of circumstances.

D. An extension to a more realistic scenario

In this section, we provide a coherent economic argument for foreclosure inspired by the theory of Choi and Jeon and more closely approximating the facts of the Android case. We describe the intuitive rationale for conduct that causes entry deterrence and harms consumers by tying, but leave the formal model to Appendix.

A key question in the Android case is whether an efficient rival search engine that offers an equivalent (or better) quality compared to Google

Search can outbid Google, be pre-installed on Android devices and challenge dominance in search. We show that when Google ties the GP/GPS suite to Google Search it can outbid a more efficient search engine, and therefore deter entry, as long as Google has committed to distributing Android with the GP/GPS suite without charging the OEMs. This commitment generates a "quality gap" compared to "bare" Android devices that lack this suite. This fits what is observed in the market, where Google committed to providing both Android and its GP/GPS suite for free.[20]

Of course, there are multiple reasons why Google has provided its GP/GPS suite without charging OEMs. In the first place, this approach has been crucial to convince OEMs to adopt its OS when first launched in 2007, and persuade consumers to opt for Android devices. When proprietary OSs such as Symbian and Windows Mobile (with their application stores) were the main options for OEMs, Google had to convince them that Android (with its application store) would have matched their price-quality ratio in the near future. By committing to an open source OS with a free application store and a free application programming interface, Google convinced application developers to build applications for Android and created the basis for the quality advantage of its application store and, more generally, of the Android devices.

Naturally, because the market for application stores is two-sided, Google can always monetize its services on the advertisers' side, namely by getting a percentage of revenues from application developers, through in-app advertising powered by Google products, and through the promotion of the Google environment which generates revenues from its traditional search advertising business. This increases usage of Android devices and rationalizes pricing on one side only – a feature which is common to most two-sided platforms. Interestingly, Amelio and Jullien[21] have shown that a two-sided monopolist constrained to set non-negative prices would naturally give out for free its main service to one side with the purpose of maximizing usage and revenues on the

[20]As it will be clear from the following analysis, what matters for our argument is not that Google has committed to distribute GP/GPS exactly at a zero price, but that it cannot extract all its extra value for the consumers. This generates an uncollected surplus that can be exploited to deter entry with tying. Accordingly, the argument is much more general than under the assumption that OEMs are not charged for GP/GPS. Nevertheless, we maintain this assumption because this is what occurs in the market. We are grateful to Robert Stillman for many insightful discussions on these points.

[21]Amelio and Jullien, *supra* (n 1). For a classic reference on why two-sided software platforms tend to price only on one side of the market see Davis Evans, Andrei Hagiu and Richard Schmalensee, *Invisible Engines: How Software Platforms Drive Innovation and Transform Industries.* (MIT Press 2008).

other side. But they have also shown that, since this constrained pricing is suboptimal, the monopolist can exploit tying to increase its profits.

Let us now consider a situation in which OEMs put together hardware, the Android OS, an application programming interface with an application store, and a search engine when assembling their Android devices. They then compete in prices to sell devices. Consumers buy the device with the best price-quality differential, taking into account the quality of its software components. We assume a strong form of default bias, in which consumers use the search engine that is pre-installed as the default search engine.

Let us also assume (as indeed is the case) that Google provides Android to all OEMs for free. Google also provides the GP/GPS suite for free – this suite has additional value for consumers compared to alternative suites, because it includes unique applications, such as GooglePlay and YouTube, which are not available otherwise. Google monetizes the suite, if adopted by the OEMs and therefore used by consumers, on the advertising side, where all rents are extracted through in-app advertising and revenue share agreements with application developers.

Finally, let us assume that search engines can be provided by two firms: Google provides Google Search, and an entrant provides a search engine of superior quality. As usual in these analyses, we focus on a more efficient entrant to show that foreclosure can take place even if the product of the entrant is preferred by consumers. Search advertising gains can be collected by each search engine used by a consumer, and we assume that both search engines can extract the same revenues from online advertising.

We compare two scenarios. In the first scenario, there is no tying, so Google provides the GP/GPS suite as a standalone product and competitive bidding for exclusive pre-installation of search engines takes place. Since the entrant is assumed to provide a superior search engine, it can outbid Google Search for pre-installation. The outcome is that OEMs "mix and match" products (Google suite with the rival search engine). Google obtains profits from the advertising side of the market and app developers through the GP/GPS suite, the entrant obtains profits from search advertising minus a payment to OEMs, and consumers buy devices with the best software (the best app store and the best search engine) at a relatively low price. The outcome is efficient.

The second scenario involves Google tying its suite with Google Search. This mirrors what happens in practice: Google makes GP/GPS available if and only if Google Search is pre-installed as the default search engine – but does not make it available to forked Android devices that do not sign MADAs and AFAs. While an entrant can still bid for exclusive pre-installation on forked Android devices without GP/GPS, the difference in quality makes it possible for Google to pay OEMs enough to use its bundle. In practice this happens through the RSAs. Under some additional conditions, this strategy deters entry, is profitable for Google, and reduces the price–quality ratio of mobiles compared to the previous situation without tying. Accordingly, consumer surplus decreases because of tying.

The key condition for this result is that in the absence of tying, Google forgoes collecting some surplus from OEMs through its commitment to a zero price for the GP/GPS suite. This "uncollected surplus" is then used to capture the tied good market.[22] In practice, the difference in quality between "normal" Android devices with the GP/GPS suite, and "bare" Android devices without it is so large that through small financial incentives Google can convince OEMs to adopt the GP/GPS suite, and rival search engines cannot outbid Google.[23] Notice that if Google had set a monopolistic price for the standalone GP/GPS suite, the price would equal the incremental value of the GP/GPS suite compared with an alternative suite, and exclusive tying would no longer be profitable. However, when there is some constraint on pricing for the product in the primary market, the One Monopoly Profit Theorem breaks down.

A number of precise results emerge from our baseline model.

First, tying deters entry of a rival search engine – at least as long as the extra gains for consumers from the GP/GPS suite are greater than the differences in quality between search engines. This does not seem to be an unreasonable and unrealistic condition.

Second, foreclosure requires financial incentives for the OEMs to adopt the bundle if the total surplus generated by the rival search engine (for both consumers and firms) is higher than the consumer surplus generated by the tying product. Again, this condition appears reasonable and provides a rationale for the financial incentives that are currently given by Google to OEMs for exclusivity through RSAs. However, the model suggests a more subtle interpretation of these incentives: they do not really pay for exclusivity, which is de facto obtained with the MADAs already, but they provide side payments to the OEMs to make sure that

[22]Early insights on this point were already in Whinston, *supra* (n 3), and Jay Pil Choi, 'Preemptive R&D, Rent Dissipation, and the Leverage Theory' (1996) 111(4) Quarterly Journal of Economics 1153.

[23]One may also note that, when the production of mobile devices is monopolized rather than being competitive (as for iPhones compared to Android devices), Google would have to pay a much larger financial incentive to the monopolistic OEM to obtain exclusive installation of Google Search. This is indeed what happened with Apple.

they are willing to accept the MADAs and install the GP/GPS suite rather than using alternative forked devices.

Third, foreclosure reduces both welfare and consumer surplus, which is a fundamental difference with the Choi and Jeon model where tying reduces welfare but not consumer surplus. The way foreclosure reduces total welfare in our model is simple: tying leads to the use of an inferior search engine. The way in which it reduces consumer surplus, however, is more interesting. Without tying, the monopolist extracts surplus in the primary market on the advertising or app developer side – and not on the consumer side. However, with tying, the monopolist can also extract the surplus derived from the primary product on the consumer side, after compensating consumers only for giving up to the superior search engine. The loss of the consumers is the gain of Google.

Last, tying can also increase the price of mobile devices – beyond reducing quality due to the loss of the superior search engine – if the extra gains for consumers from the GP/GPS suite are much larger than the difference in quality between search engines. Of course, this is related to the change in consumer surplus, but it is again the opposite result of what emerges in the Choi and Jeon model (where tying would always reduce the price of mobile devices). This shows that tying can increase not only the price–quality ratio of mobile devices, but also their actual price. As a corollary to the previous result, we emphasize that it is even possible that foreclosure requires positive payments to OEMs, at the same time increasing the price of mobile devices and reducing their quality for the final users: these are of course circumstances in which tying is extremely detrimental to consumers.

The basic insight in this analysis goes back to the main insight of the Choi and Jeon model: tying can be profitable if there is some limit to pricing in a two-sided market (this is the secondary market in the original Choi and Jeon model and the primary market in ours). But importantly, it should be clear by now that our argument does not rely on the exact commitment to a zero price of the GP/GPS suite: as long as Google is unable to extract all the surplus of consumers from the suite, there is space to deter entry in a profitable way. To show this, the Appendix presents also a generalization of the model to heterogeneous preferences of consumers and optimal linear pricing of the GP/GPS suite as a standalone product.

Our main new result is that when consumers are heterogeneous in preferences, tying is anti-competitive also if Google sets the optimal linear price for the GP/GPS suite as a standalone product. The intuition is that a linear price for the GP/GPS suite without tying does not allow

Google to extract all the surplus of the heterogeneous consumers. Therefore, there is always an unexploited surplus that can be recovered through the tying strategy, which allows Google to attract consumers with the highest evaluation of normal Android devices reducing the payment needed to convince OEMs to accept the bundle. In such a case, the tying strategy allows some forked devices to be produced with the rival search engine pre-installed, but Google can still profit from this strategy if the revenues from app developers and in-app advertising are low enough (since these are lost on the forked devices) and the quality gap between search engines is low enough (since this limits the payments to OEMs to accept the bundle). With heterogeneous consumers, tying is inefficient because it forces some users to adopt the less efficient search engine by buying normal Android devices and it also forces the remaining users not to adopt the efficient suite by buying a forked Android device. When profitable, tying can also reduce consumer surplus if the revenues from app developers and in-app advertising are low enough and the quality gap between search engines is low enough. Therefore, the anti-competitive nature of the tying strategy of Google holds under rather general conditions.

Our baseline model can be also extended to include providers of alternative application stores for Android devices.[24] These could also obtain revenues from application developers and advertisers and, therefore, give monetary incentives to OEMs to adopt their application stores in combination with another search engine on a forked device. Their presence would simply increase the payments that Google has to offer to convince the OEMs to accept its bundle. Accordingly, RSAs can be seen as a tool to foreclose at the same time the entry of competing search engines, competing app stores and producers of forked devices. Therefore, the incentives that Google offers to the OEMs through the RSAs should be seen as side payments to accept the restrictions contained in its agreements.[25]

An auxiliary factor in the foreclosing strategy of Google stems from the AFAs, which apply at the company level: OEMs signing an AFA can only sell normal Android devices and cannot diversify their activity by selling modified Android devices. Only OEMs that do not sign MADAs and AFAs can potentially develop and sell these alternatives. This exacerbates

[24]We are indebted with Robert Stillman for pointing out this additional element.

[25]Notice also that RSA payments by Google are generally lower than by its search rivals, but Google offers global agreements that leave little room for regional players, who are more efficient, to compete for pre-installation.

foreclosure of entry by the leading mobile producers in what is currently a niche market for forked Android devices. Such a market could also involve competitive pressure for the producers of normal Android devices, but this is precluded by the AFAs. This defensive leveraging reduces platform differentiation, which is problematic in a field where there is limited direct competition at the retail level between Android and Apple iOS – since Apple is confined to the high-segment market (and its OS is non-licensable to other OEMs). Our model can be easily amended to include the role of the AFAs. Suppose that signing an AFA reduces profit opportunities for an OEM: then the RSAs must compensate also for these lower profit opportunities. As before, the incentives that Google offers to the OEMs through the RSAs are side payments to accept the restrictions contained in both the MADAs and the AFAs and protect its search business.

A lively market for forked Android devices would be crucial for the survival of all the application developers foreclosed by Google in the applications market for normal Android devices. They could commercialize their products on forked Android devices and gain new consumers, economies of scale and network effects. However, this again is difficult due to the AFAs, which preclude entry into this market for the main producers of Android devices. As noted elsewhere,[26] this factor reinforces the exclusionary effects induced by the MADAs and the RSAs on competing search engines. On one side, they cannot provide their products on normal Android devices – where Google Search is already pre-installed and potentially under exclusionary provisions – and on the other side they cannot find a relevant market for forked Android devices where they can distribute their products or possibly pay OEMs for exclusive pre-installation. By precluding this possibility, AFAs indirectly penalize product differentiation and innovation in applications for Android devices, which ultimately hurts consumers. As we will see in the next section, this may be part of a more general exclusionary strategy by Google.

E. Additional mechanisms of naked exclusion that reduce the side payments to OEMs

While we have emphasized above a new self-contained theory of harm for the Android case, this can be reinforced by an additional mechanism that is well known in the theoretical literature. It has to do with what is usually referred to as the "naked exclusion" of rivals through exclusive dealing

[26]Edelman and Geradin, *supra* (n 1).

contracts.[27] As we have seen, Google signs RSAs with a group of selected large OEMs. We have already shown how these RSAs can be decisive to foreclose entry, yet Google can also exploit its dominance by bargaining with OEMs in a way that minimizes its payments. Essentially, this happens with a "divide-and-conquer" strategy.

Google has a technological leadership in search, and a dominance in online advertising that can be threatened only if a competing search engine manages to develop a sufficient scale to endogenously improve its search algorithms (known as "scale in search"), and to attract enough search queries to expand revenues in online ads and further invest in innovation ("network effects").[28] Both these elements explain why a rival search engine can only expect to compete with Google Search if it builds a large enough scale (i.e. reaches a large enough number of users). Indeed, while the technological and consumer-based determinants of these scale economies are peculiar to this market, the ultimate implications are similar to what occurs in any market with a large enough minimum efficient scale.

It is well established in the economic literature that, under certain circumstances, a dominant firm can adopt a network of exclusive dealing arrangements to deter entry of existing or potential rivals and harm consumers: this is usually defined as "naked exclusion". The argument behind this form of vertical foreclosure is due to Rasmusen–Ramseyer–Wiley and applies in the present context when appropriately modified.[29] The additional aspect that must be introduced is given by "scale economies" due to scale in search and network effects. Competing search engines can enter the market or expand their market share by building "scale in search" only if they reach a high enough share of users. Contracts for pre-installation of their search engine on some OEMs' devices are a viable opportunity (in practice the only one) for this. However, dominance

[27]Other theories of anti-competitive exclusive dealing rely on payments due in cases of breached exclusive contracts (Philippe Aghion and Patrick Bolton, 'Contracts as a Barrier to Entry' (1987) 77(3) American Economic Review 388) and pervasive forms of asymmetric information generating complex contracts (Giacomo Calzolari and Vincenzo Denicolò, 'Exclusive Contracts and Market Dominance' (2015) 105 (11) American Economic Review 3321). Recent theories apply in environments that are more similar to ours, with simple exclusive dealing contracts that can be offered by the incumbent firm and competing agreements that can be offered by its rivals (see Patrick DeGraba, 'Naked Exclusion by a Dominant Input Supplier: Exclusive Contracting and Loyalty Discounts' (2013) 31 International Journal of Industrial Organization 516; David Spector, 'Exclusive Contracts and Demand Foreclosure' (2011) 42(4) RAND Journal of Economics 619).

[28]For a related analysis on the economics of search advertising and antitrust concerns in this sector, see Federico Etro, 'Advertising and Search Engines. A Model of Leadership in Search Advertising' (2013) 67 (1) Research in Economics 25.

[29]See Rasmusen *et al.*, *supra* (n 5).

in search puts Google in an asymmetric position compared to rival search engines. This is due in part to Google's superior technology, which gives an initial advantage in attracting users – and therefore OEMs willing to sell exclusivity – and in part to the pre-installation of Google Search as a default search engine.

In such a context, characterized by a competitive downstream market for Android-based mobile devices, the dominant firm in search can exclude entrants by selecting major OEMs and offering them RSAs for exclusive pre-installation of its search engine. A large enough proportion of the OEMs can be paid for exclusivity so that rival search engines cannot reach the necessary scale to become a threat even if they manage to establish agreements with all the remaining OEMs. Dominance and asymmetry in technological conditions allow Google to systematically outbid potential rivals[30] in these agreements for a classic pre-emption argument: the incumbent has more to lose than entrants have to gain when there is free entry in a bidding competition, and therefore the incumbent outbids its rivals.[31] Indeed, since Google has a technological lead that allows its search engine to deliver higher ad revenues, it also generates – endogenously – the resources needed to win exclusivity and reinforce its lead.

The economic literature has pointed out a consequence that is even more disruptive for competition: in expectation of the scenario in which the dominant firm outbids its rivals and deters entry, the dominant firm can bargain with the OEMs one by one in a strategic way and minimize the payments for exclusivity. In theory this can lead to zero-price payments.[32] In practice it allows Google to pay much less than in the case of bilateral bargaining. The possibility of such a "divide-and-conquer" strategy with reduced payments to selected downstream OEMs to sign exclusivity arises from a coordination failure between these downstream firms, allowing them to be exploited by the dominant upstream firm.

Remarkably, in the presence of a monopolized downstream market, such as the one for iOS-based mobile devices of Apple, the coordination failure between OEMs would vanish and the dominant firm in search

[30]Notice that in what follows we are abstracting from our earlier argument for which Google can outbid a more efficient search engine. That earlier argument and the one presented in this section are clearly reinforcing each other.

[31]See Richard J. Gilbert and David Newbery, 'Preemptive Patenting and the Persistence of Monopoly' (1982) 72(3) American Economic Review 514.

[32]See Ilya Segal and Michael Whinston, 'Naked Exclusion: Comment' (2000) 90(1) American Economic Review 296.

would have to exclude entrants in search by paying the downstream monopolist enough to outbid all the rivals. This would require a substantially higher payment in comparison to the fragmented scenario above. But this appears exactly in line with the large payments made by Google to Apple for exclusivity of Google Search on the iPhone and the iPad. This confirms that online competition is not "one click away" when the default bias is relevant.

F. Final considerations

An entry-deterring strategy such as that articulated in this paper generates at least three sources of consumer harm.

First, entry deterrence eliminates gains from the provision of better or differentiated search engines. As mentioned above, in spite of Google's technological lead, different search engines can provide results that are differentiated for depth and range of outcomes, with different specificities, for different types of queries. Constraints to multi-homing thus create losses for consumers (especially as search engines do not use relevant disk space since their services are provided through remote servers).

Second, anti-competitive tying makes it impossible for rivals to build scale in search and effectively compete with Google, eliminating pressure on Google to reduce its margins in online advertising. This has negative consequences for advertisers and, ultimately, for consumers. It can also translate into more intrusive advertising and larger collection of consumer data by Google without viable alternatives for consumers.

Third, entry deterrence in search can reduce Google's incentive to invest in innovation, as an unchallenged dominant firm has lower need to improve its technologies. This also reduces the incentive for potential entrants to invest in R&D in the markets for search engines and for software applications in general (including application stores and browsers). All this leads to long run losses for consumers.

What could a potential solution look like? While remedies in these cases are often an opaque process which results from complex negotiations and trade-offs behind the scenes, a few comments can be made.

A first measure to address the tying aspect of the MADAs could be to require that Google offers the GP/GPS suite on a standalone basis. This would extend to pre-empting Google from offering directly or indirectly a bundle that included other services at prices that are lower than the sum of the prices at which it offers GP/GPS on a standalone basis. This last provision would be required to prevent Google from evading the unbundling remedy with a pricing that would make standalone products artificially non-attractive. Other commentators have noted that Google could then charge a positive fee for some of its products:[33] our analysis suggests that Google could indeed charge OEMs a positive price for the GP/GPS suite alone. However, the benefit for OEMs and consumers would be in the opportunity to have devices with GP/GPS matched with alternative search engines as well as other applications, generating product differentiation in mobile devices and applications, and intensifying competition.

A second measure to address the foreclosing effects of the AFAs could be to require that Google cannot forbid OEMs from commercializing forked Android devices if they also commercialize "Google compatible" Android devices. This would enhance product differentiation and competition on the merit between OEMs without undermining the "Google compatible" ecosystem, and it would allow manufacturers and app developers to diversify their production through forked Android devices.

A third measure to address the entry-deterring implications of the RSAs could be to require that Google does not offer payments to OEMs (and MNOs) conditional on exclusivity of its search engine (or pre-installation of GP/GPS or other Google's product). This would allow rival search engines to pay OEMs for pre-installation and outbid Google for RSAs. Competition between search engines would be on the merit, with multi-homing and payments to OEMs shifted entirely or partially to consumers through lower prices for the Android mobiles. Of course, this would also enhance investments in innovation for the creation of new and better search engines and other software applications.

As the Microsoft Windows Media Player case has shown, an unbundling remedy can be extremely ineffective when it is not complemented by further measures. The restoration of a level-playing field is of course challenging in this case given Google's extreme levels of dominance. A possible measure could be to allow OEMs that wished to be engaged in exclusivity arrangements with competing search providers to do so; at the same time, OEMs that wished to do so could also offer consumers the opportunity to set Google Search as the default search engine by presenting them with a "choice screen" where consumers should select one of multiple options. This would not involve a bias in favour of the dominant search engine but would allow consumers to choose Google Search or any other

[33]Edelman and Geradin, *supra* (n 1).

alternative as a default – as part of a conscious choice. In effect a choice screen remedy would move the default decision from OEMs to consumers, and this would protect from concerns about possible retaliation against OEMs willing to opt for a different default search engine.

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Appendix. A formal model of anti-competitive tying

In this Appendix we formalize the basic mechanism of our economic argument extending the model of Choi and Jeon. The model is based on multiple OEMs assembling software and hardware into Android devices, sold to final consumers under price competition.[34] Google is assumed to be a monopolist on the GP/GPS suite including YouTube and other applications without substitutes. However, Google Search faces entry in the market for search engines from a more efficient rival. We allow search engines to bid for exclusivity on mobile devices produced by OEMs. We first consider homogeneous consumers and then extend the model to the case of heterogeneous consumers.

In the baseline model, if Google sets a monopolistic price for the GP/GPS suite on both OEMs and in-app advertisers, and the search engines bid for exclusivity, the One Monopoly Profit Theorem holds (in the sense that Google cannot increase its monopolistic profits by tying Google Search to foreclose entry of the rival search engine), but it breaks down under the constraint that Google has committed to give its valuable GP/GPS suite (with YouTube and possibly other applications without substitutes) for free to OEMs, while it extracts the full monopolistic rents from app sales and in-app purchases. By doing this, Google forgoes collecting some surplus from the OEMs, and this uncollected surplus can be used to capture

[34]Under price competition between multiple OEMs, there is full pass-through of any cost reduction into lower prices of mobile devices. Incomplete pass-through due to imperfect competition would not change qualitatively the results. However, the market for Android device manufacturer is quite competitive and the assumption of full pass-through can be regarded as realistic. We are thankful to Pierre Regibeau for comments on this point.

the tied good market.[35] We then show that when consumers are heterogeneous, the commitment to give the suite for free is not needed and the inability of Google to extract all the related surplus from the OEMs with a linear price is enough to make bundling profitable and anti-competitive.

A.1. Baseline framework with homogeneous consumers

Consider consumers buying Android mobile devices from many OEMs engaged in price competition. Each OEM assembles hardware, OS, software and a search engine as perfect complements in the production of a mobile device. Hardware has a cost c per device. This is assumed the same for any OEM to focus only on differences in software. The Android OS is provided freely to any OEM under the open source commitment. Its value to consumers is normalized to zero.

The GP/GPS suite including YouTube and other applications is provided by Google and has value $x > 0$, assumed identical for each consumer. It also generates advertising gains $\alpha > 0$ from each user (from in-app revenues), which can be fully extracted by Google. Alternative suites with application programming interfaces and application stores are available but their value for a consumer is lower because they do not have Google Play, YouTube and other apps in the GP/GPS suite: their value is normalized to zero so that the quality degradation of forked Android devices is x.

Two search engines are available. Google Search has value $v_G > 0$ for each consumer. An "as efficient" entrant E provides a superior search engine whose value is $v_E \geq v_G$ with quality advantage $\Delta \equiv v_E - v_G \geq 0$. The search advertising gains per user of a search engine are $\beta > 0$ and can be fully extracted by the provider of the search engine which is used by consumers.

We assume $x > \Delta$ and $\beta > \Delta$ so that the surplus created by the GP/GPS suite for a user and the advertising gains created by its use of search engine are both larger than the quality gap between search engines.

The timing of the game is as follows:

(1) Google decides whether to commercialize separately its GP/GPS suite and Google Search or to tie them (in ways specified below);
(2) Google and the entrant offer payments to OEMs for each mobile device sold;
(3) OEMs can accept an offer, and put together hardware, Android, the suite and the search engine into a mobile device;
(4) OEMs set prices for their mobile devices;
(5) Consumers buy the device that maximizes their consumer surplus.

In what follow we assume that there are many OEMs in price competition to sell mobiles, which insures marginal cost pricing. We initially assume a unit mass of

[35]Exclusive tying forces the rival search engine to bid for a forked Android device with an alternative suite, whose value for the consumers is lower. Google can pay OEMs to take on board its bundle, possibly through payments to OEMs low enough to deter entry and make more profits than without tying. Note that if Google had set a monopolistic price for the standalone GP/GPS suite, that price would be the incremental value compared to an alternative suite, extracting all the surplus created, and exclusive tying would no longer be profitable.

identical consumers, which implies that only one mobile and one search engine is chosen in equilibrium (later we will consider heterogeneous consumers).[36]

Our last assumption is that Google cannot set a positive price for its GP/GPS suite. This is actually the constraint present in this market, since Google has committed to a zero price for both Android, through the open source commitment, and its suite for the OEMs, and monetizes its application store through in-app revenues. Under this condition, we can show that tying by Google deters entry.

Without tying Google is committed to giving the GP/GPS suite for free, and this is used by all OEMs since it is superior to any alternative: from this Google gains α from in-app revenues. Moreover, Google is willing to bid up to $b_G = \beta$ per user for exclusivity of its search engine. However, the entrant has a superior product and can outbid Google by paying the OEMs an amount $b_E = \beta - \Delta > 0$ per user. The OEMs obtain the GP/GPS suite for free and match it with the search engine of the entrant, selling mobiles at the price:

$$p = c + \Delta - \beta.$$

The profits of the two firms are:

$$\pi_G = \alpha \quad \text{and} \quad \pi_E = \Delta.$$

Consumer surplus is:

$$CS = x + v_E - p = v_G + x + \beta - c,$$

and total welfare is $W = \alpha + \beta + x + v_E - c$ which is the first best level.

With tying Google can increase its profits by tying its two products: in such a case, it bids b_G for exclusive pre-installation of the bundle: this payment can be seen as a device-based RSA conditional on exclusive pre-installation of Google Search. Given the restrictions imposed by Google, the best the entrant can do is to bid b_E for exclusive pre-installation on a forked Android device. For this, the entrant is always able to bid up to $b_E = \beta$ per user, which would generate a minimum price $c - \beta$ for its bare Android device. Since the bid of Google b_G generates a price $c - b_G$ for normal Android devices, Google can deter entry if:

$$x + v_G - (c - b_G) \geq v_E - (c - \beta),$$

which holds when Google pays OEMs at least $b_G = \Delta + \beta - x$. Incidentally, notice that under our assumptions, this bid could be positive (a payment to the OEMs), zero or negative (a payment from the OEMs). As a consequence of such a bid, only normal Android devices are sold at the price:

$$p^* = c + x - \Delta - \beta,$$

and the profits of Google are now:

$$\pi_G^* = \alpha + x - \Delta,$$

[36] Notice that we do not consider any fixed costs of entry or economies of scale (due to scale in search or network effects): this is to be as parsimonious as possible, since additional entry barriers would open up obvious opportunities for foreclosure and naked exclusion to emerge.

which is always above the profits without tying, $\pi_G = \alpha$, under our assumption that $x > \Delta$.

Consumers use the inferior search engine with consumer surplus:

$$CS^* = v_G + \Delta + \beta - c < CS = v_G + x + \beta - c,$$

which holds because $x > \Delta$. Therefore, tying reduces consumer surplus. The reason for this is that it allows the monopolist to extract the large consumer surplus derived from the primary product, compensating consumers only for giving up the smaller surplus of the superior search engine. Total welfare is now $W^* = \alpha + \beta + x + v_G - c$, which is also below the first best level obtained without tying in this environment. Summing up, our first main result is the following:

PROPOSITION A1. *Tying deters entry of the rival search engine and reduces both consumer surplus and welfare as long as* $x > \Delta$, *that is, the extra gains from the tying product for the consumers are above the quality difference between search engines.*

Therefore, the quality degradation of the forked Android devices is key to anti-competitive foreclosure. This derives from the restrictions imposed by the MADAs that only make the GP/GPS suite available with Google Search tied. It appears reasonable that the extra gains from GP/GPS are higher than the extra gains from existing search engines, and remarkably this is a necessary and sufficient condition not only for foreclosure to happen but also for consumer surplus to decrease with it.

The model can also rationalize the role of RSAs. We can verify that positive financial incentives are paid by Google to the OEMs for the adoption of the bundle if $\Delta + \beta > x$. Using the previous result, we have our second main result:

PROPOSITION A2. *Foreclosure requires financial incentives paid by Google to the OEMs for the adoption of the bundle if* $x \in (\Delta, \Delta + \beta)$, *which requires that the total surplus generated by the rival search engine (for both consumers and firms) is higher than the consumer surplus generated by the tying product.*

The condition for positive financial incentives from Google is again reasonable in this context because the advertising gains from mobile search are the main revenues that can be obtained in this market, and indeed the core business of Google. This provides a rationale for the financial incentives given by Google to OEMs for exclusivity through the RSAs. In particular, if payments per device are $b_G = \Delta + \beta - x > 0$ and the revenues from search advertising per device are β, their ratio is $\text{RSA} = 1 - (x - \Delta)/\beta$.

However, the model suggests a more subtle interpretation of these incentives: they do not really pay for exclusivity, which is de facto obtained by MADAs already, but they make sure OEMs are willing to accept the MADAs and install the GP/GPS suite rather than using alternatives.

We can make further comparisons. In particular, we can compare the price of Android devices in the two scenarios: $p = c + \Delta - \beta$ without tying and $p^* = c + x - \Delta - \beta$ with tying. Tying can increase the price of mobile devices, in spite of their inferior quality due to the lack of the best search engine. In particular, we have:

PROPOSITION A3. *Foreclosure increases the price of mobile devices if $x > 2\Delta$, that is when the extra gains from the tying product for consumers are at least twice the quality difference between search engines.*

Under our assumptions this is perfectly possible: large enough gains from the GP/GPS suite imply that tying increases the price of devices. As a corollary of our earlier results foreclosure increases the price of mobile devices even if Google pays OEMs for pre-installation as long as $x \in (2\Delta, \Delta + \beta)$.

We conclude this section mentioning what already shown by Choi and Jeon. If Google can set an unconstrained price q for the suite as a standalone product, this price is set as $q = x$ and the profits of Google without tying become $\pi_G = \alpha + q = \alpha + x$. Since these are above the profits with tying, tying is not profitable and the One Monopoly Profit Theorem holds. This is the reason for which some constraint on the ability of Google to fully extract rents from the primary product without tying is crucial for the result.[37]

A.2. The model with heterogeneity in consumers' preferences

In this section, we extend the framework to heterogeneous consumers to show that tying can be adopted under more general conditions. The only difference compared to the baseline model is that the unit mass of consumers has a value for the tying good uniformly distributed on the unit line:

$$x \sim U[0, 1].$$

This can be interpreted as the relative preference for the GP/GPS suite compared to other suites or as the preference for a high-quality app store compared to a high-quality search engine. The consequence is that we may have the coexistence of both normal and forked Android devices, with consumers with high valuation for the GP/GPS suite buying normal Android devices and consumers with a low evaluation (and a relatively higher evaluation for better search engines) buying a forked device. In spite of this, we will show that tying can be still a profitable device and reduce the profits of a more efficient rival search engine.

In what follows we look for interior solutions under tying, neglecting the analysis of corner solutions with entry deterrence. We assume that the GP/GPS suite delivers ad revenues $\alpha < 1$ for each normal Android device, and each search engine delivers ad revenues β per device, and the quality gap between search engines is $\Delta < 1/2$. As before, OEMs are competitive and their prices reflect the marginal cost of production.

[37]We can mention a generalization of our main result, suggested by Robert Stillman. Let us suppose that there is an alternative app store which does not provide the extra value x to consumers, but can pay OEMs for installation up to the gains $\alpha > 0$ that can be obtained from app sales or in-app purchases after installation. Moreover, let us assume that without tying Google has committed to adopt a price $q < x - \alpha$ for the GP/GPS suite as a standalone product. Notice that the upper bound $x - \alpha$ is now the optimal price for the suite as a standalone product (due to the outside option of the alternative app store). This implies that the price constraint is softer than what assumed in the main model (where we assumed $q = 0$). In spite of this, similar derivations to those above show that entry deterrence is profitable and reduces consumers surplus if and only if $q < x - \Delta - \alpha$. In practice, even in the presence of a negligible positive constraint on pricing, entry of an equally efficient or slightly more efficient search engine is always foreclosed by Google through tying, increasing its profits and reducing consumer surplus.

As before, also in this section, Google sets a zero price for the suite as a standalone product (we will drop this assumption in the final section).

Without tying heterogeneity does not play a substantial role. The efficient search engine can always outbid Google to install its own search app on any device. Therefore, only normal Android devices are commercialized with the efficient rival search engine installed on all of them, as in case of homogenous consumers. All consumers purchase a normal Android device, even if their utility changes with their evaluation of the GP/GPS suite. The profits of the two firms are always:

$$\pi_G = \alpha \quad \text{and} \quad \pi_E = \Delta.$$

And the price of mobiles remains $p = c + \Delta - \beta$ as before. Consumer surplus takes into account the average evaluation of the suite:

$$CS = v_E - p + \int_0^1 x\mathrm{d}x = v_G + \beta - c + \frac{1}{2}.$$

As before, this is the efficient outcome because all users employ the most efficient search engine and the suite.

With tying, suppose that Google pays the OEMs b_G for each normal Android device with its search engine installed, and the rival search engine pays b_E the producers of forked Android devices for each unit sold with its search engine installed. The consumer who is indifferent between buying a normal device and a forked device is characterized by the type $\hat{x}$ such that:

$$\hat{x} - (c - b_G) + v_G = v_E - (c - b_E).$$

where on the left-hand side is the utility from a normal Android device (with the value of the suite $\hat{x}$ and of Google Search v_G, and a price given by the cost of hardware net of the payment per device given by Google to producers, $c - b_G$) and on the right-hand side is the utility from a forked Android device (with the value of the rival search engine v_E and the price given by the cost of hardware net of the payment per device from the search engine to producers, $c - b_E$). The condition can be rewritten as

$$\hat{x} = \Delta - b_G + b_E.$$

As long as this is between 0 and 1, it represents the demand for the rival search engine. Accordingly, we can state the profits of Google and the rival search engine as follows:

$$\pi_G = (1 - \hat{x})(\alpha + \beta - b_G) = (1 - \Delta + b_G - b_E)(\alpha + \beta - b_G),$$

and

$$\pi_E = \hat{x}(\beta - b_E) = (\Delta - b_G + b_E)(\beta - b_E).$$

We can now look for the profit maximizing payments offered by Google and the rival search engine to the OEMs. The first-order conditions of Google to maximize π_G with respect to b_G and of the rival search engine to maximize π_E with respect to b_E are:

$$b_G = \frac{\alpha + \beta - 1 + \Delta + b_E}{2},$$

and

$$b_E = \frac{\beta - \Delta + b_G}{2}.$$

These reaction functions emphasize that higher payments to OEMs by one firm lead the other firm to pay OEMs more, strategic complementarities that were absent with homogeneous consumers. Moreover, they show that larger search advertising revenues β increase the payments of both firms, and the quality gap in search engines exerts opposite effects on the optimal bids. Finally, larger revenues from the suite α incentivise (only) Google to pay OEMs more because this expands the number of users on which in-app revenues are created. This is a new effect compared to the case with homogeneous consumers and it is due to the demand side: when Google gains more from the suite, it has higher incentives to reduce the price of normal Android devices to expand usage.

The Bertrand equilibrium implies payments:

$$b_G = \frac{2\alpha + 3\beta + \Delta - 2}{3},$$

$$b_E = \frac{\alpha + 3\beta - \Delta - 1}{3}.$$

Taking into account strategic interactions, both sources of revenues incentivise the firms to increase their payments to OEMs, but Google is more sensible to its own revenues. The equilibrium production of forked devices is:

$$\hat{x}^* = \frac{\Delta + 1 - \alpha}{3} \in \left[0, \frac{1}{2}\right],$$

which is null when $\Delta = 0$ and $\alpha = 1$ and a half when $\Delta = 1/2$ and $\alpha = 0$: normal Android devices have the majority of the market under our assumptions. The equilibrium profits are:

$$\pi_G^* = \left(\frac{2 + \alpha - \Delta}{3}\right)^2 \quad \text{and} \quad \pi_E^* = \left(\frac{1 - \alpha + \Delta}{3}\right)^2,$$

where we keep denoting with a star the equilibrium values under tying. Strategic interactions with heterogeneous consumers imply that both profits depend (differently) on both the quality gap Δ and Google's revenues from the suite α. Notice that under our assumption Google obtains always more profits than the rival search engine.

We can now derive some conclusions. First of all, a comparison of π_G^* with $\pi_G = \alpha$ shows that tying is profitable for Google as long as $\Delta < 2 + \alpha - 3\sqrt{\alpha}$ or:

$$\alpha < \bar{\alpha}(\Delta) \equiv \left(\frac{3 - \sqrt{1 + 4\Delta}}{2}\right)^2,$$

which is a wide set since $\bar{\alpha}(\Delta) \in (0.4; 1)$: tying is always profitable to contrast an as efficient rival ($\bar{\alpha}(0) = 1$), and it is profitable to contrast a more efficient rival if the revenues from the suite are low enough or the quality gap is low enough. This is the counterpart of Proposition 1 in the presence of heterogeneous consumers. The intuition follows from the baseline model, since tying allows Google to use the unexploited surplus from GP as a standalone product to gain users of Google Search, and these users are those that value GP/GPS the most relative to the search engine, which makes it cheaper to attract them. The counterpart of this is that Google allows some forked devices to be developed on which it does not raise any revenues. For this reason the gains from tying increase when revenues from the suite become less important compared to the revenues from search advertising and when the quality gap in search engines is small.

Second, a comparison of π_E^* with π_E shows that tying may either increase or decrease the profits of the rival search engine. When the quality gap is small tying softens competition and increases the profits of both firms.[38] However, tying reduces the profits of the rival search engine as long as

$$\alpha > 1 + \Delta - 3\sqrt{\Delta}.$$

It is easy to verify that $\bar{\alpha}(\Delta) > 1 + \Delta - 3\sqrt{\Delta}$ for any possible Δ, therefore there is always an open set of values of α and Δ for which tying is profitable and reduces the profits of the rival. Of course, in the presence of entry costs for the rival, tying would become a source of entry deterrence in the sense that entry profitable without tying becomes non-profitable with tying.

Third, in equilibrium Google pays OEMs to adopt the bundle ($b_G > 0$) if $3\beta + \Delta > 2(1 - \alpha)$ that is when the ad revenues from search advertising and in app advertising are large. This is the counterpart of Proposition 2 in the presence of heterogeneous consumers. We can also compute the payments as a fraction of the ad revenues from search advertising $\text{RSA} = 1 - [2(1 - \alpha) - \Delta]/3\beta$.

Tying creates now multiple inefficiencies. First, it forces some users to adopt the less efficient search engine buying normal Android devices. Second, it forces the other users not to adopt the efficient suite buying a forked Android device. Competition between normal and forked devices affects prices as well: the price of a normal Android devices can be computed as $p^{*\text{Google}} = c - \beta + (2 - 2\alpha - \Delta)/3$ and the price of a forked device is $p^{*\text{Forked}} = c - \beta + (\Delta + 1 - \alpha)/3$, with the latter below the former if $\alpha < 1 - 2\Delta$, which always holds if the quality gap in search engines is small. More interestingly, under the same condition, the price of normal Android mobiles is always increased compared to their price without tying $p = c + \Delta - \beta$. This is the counterpart of Proposition 3 in the presence of heterogeneous consumers.

Average consumer surplus under tying can be computed as

$$\begin{aligned} CS^* &= \hat{x}^*(v_E + b_E) + (1 - \hat{x}^*)(v_G + b_G) - c + \int_{\hat{x}^*}^{1} x\mathrm{d}x, \\ &= v_G + b_G + \hat{x}^{*2} - c + \frac{1}{2} - \frac{\hat{x}^{*2}}{2}, \\ &= CS - \frac{2(1 - \alpha) - \Delta}{3} + \frac{(\Delta + 1 - \alpha)^2}{18}, \end{aligned}$$

[38] As noticed by Choi and Jeon, this is in the spirit of the model of Jose Carbajo, David De Meza and Daniel J. Seidmann, 'A strategic Motivation for Commodity Bundling' (1990) 38(3) Journal of Industrial Economics 283.

which is always smaller than the consumer surplus without tying for Δ and α small enough: the misallocations induced by tying can reduce the benefits for consumers on average. Welfare, instead, is always reduced by tying, since the allocation without tying was efficient. We sum up with:

PROPOSITION A4. *With heterogeneous consumers, tying can be profitable for Google, reduce the profits of a more efficient search engine and reduce consumer surplus.*

A.3. Anti-competitive tying when the primary product is optimally priced as a standalone product

The remaining question we want to address is whether the constraint on the price of the suite as a standalone product is essential for tying to be profitable and reduce the profits of the rival search engine. For this purpose, we reconsider our analysis when Google freely sets its price for the suite as a standalone product. Indeed, only the case without tying is affected, because under tying there are no changes compared to the previous section. The key aspect now is that, even charging for GP/GPS as a standalone product without tying, Google cannot extract the entire surplus from its suite because of heterogeneity of consumers, and this opens the space to break the One Monopoly Profit Theorem and for the profitable use of tying.

In particular, suppose that Google can now charge OEMs the price q for each normal Android device endowed with the GP/GPS suite as a standalone product. Without tying this increases the price of normal Android devices compared to forked Android devices. The consumer indifferent between buying a normal device and a forked device is now:

$$\hat{\hat{x}} + v_E - (c + q) + \beta - \Delta = v_E - c + \beta - \Delta,$$

where the left-hand side is the utility from the normal Android device (including the value of the suite net of its price $\hat{\hat{x}} - q$) and the right-hand side is the utility from a forked device: notice that both devices have the rival search engine in this case and the price of any mobile reflects the usual payment for pre-installation from the rival search engine to the OEMs $\beta - \Delta$. The indifference condition can be rewritten as just:

$$\hat{\hat{x}} = q.$$

As long as this is between 0 and 1, this is the demand for forked devices and $1 - \hat{\hat{x}}$ is the demand for normal Android devices. The profits of Google are now:

$$\pi_G = (1 - \hat{\hat{x}})(\alpha + q) = (1 - q)(\alpha + q),$$

and are maximized by the price:

$$q = \frac{1 - \alpha}{2} = \hat{\hat{x}}^*,$$

which is indeed positive and smaller than unity under our assumption $\alpha < 1$. Notice that a larger revenue from the suite induces Google to reduce its price to expand usage: this is a simple form of network effects in this two-sided market. The profits of Google and the rival search engine, which keeps selling on all devices, are now:

$$\pi_G = \frac{(1+\alpha)^2}{4} > \alpha \quad \text{and} \quad \pi_E = \Delta.$$

Consumer surplus takes into account the average evaluation of the suite:

$$CS^q = v_G + \beta - c + \int_{\hat{\hat{x}}^*}^{1} (x - q)\mathrm{d}x.$$

A comparison of our earlier formula for the profit of Google with tying π_G^* with our last profit for Google π_G shows that tying is profitable if:

$$\alpha < \tilde{\alpha}(\Delta) \equiv 1 - 2\Delta.$$

The reason for this possibility is that heterogeneous consumers do not allow Google to extract all the surplus from a linear price for the suite. Therefore, there is always an unexploited surplus that can be recovered through the tying strategy, which allows Google to attract consumers with the highest evaluation of normal Android devices reducing the payment needed to convince OEMs to accept the bundle.

As before (since nothing is changed for the rival) tying reduces the profits of the rival search engine if $\alpha > 1 + \Delta - 3\sqrt{\Delta}$. It is easy to verify that $\bar{\alpha}(\Delta) > \tilde{\alpha}(\Delta) > 1 + \Delta - 3\sqrt{\Delta}$ for any possible Δ, therefore, there is still an open set of values of α and Δ for which tying is profitable and reduces the profits of the rival. We sum up with:

PROPOSITION A5. *Even if Google can charge OEMs for the GP/GPS suite as a standalone product, with heterogeneous consumers, tying can be profitable for Google and reduce the profits of the rival search engine.*

Comparing consumer surplus CS^q with its outcome under tying CS^* we can easily conclude that tying reduces consumer surplus if α or Δ are small enough. For instance, tying reduces always consumer surplus when applied against an equally efficient rival.