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Joacim Tåg

ESSAYS ON PLATFORMS

BUSINESS STRATEGIES, REGULATION AND POLICY IN TELECOMMUNICATIONS, MEDIA AND TECHNOLOGY INDUSTRIES

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Essays on Platforms: Business Strategies, Regulation and Policy in Telecommunications, Media and Technology Industries

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August 2008

Joacim Tåg

TABLE OF CONTENTS

PART 1: OVERVIEW

PART 2: THE ESSAYS

Part I

Overview

1 Introduction

The growth of the information economy has been stellar in the last decade. General purpose technologies such as the computer and the Internet have promoted productivity growth in a large number of sectors and have transformed the lives of a majority of individuals in the industrialized world.

The effect on the telecommunications, media and technology sectors has been particularly strong. These sectors cover a wide range of industries, such as mobile telecommunications, printing and publishing, broadcasting, software, hardware and online services. There have also been large structural changes. For example, there has been a shift from transporting telephone calls and fax messages to transporting data, traditional publishing and broadcasting companies have become better at tailoring content and advertisements, and platforms such as auction sites, online books stores, software programs, and hardware devices have become more common.

These structural changes have led to new questions on business strategies, regulation and policy. This thesis focuses on four such questions:

- Do we need to regulate how Internet service providers discriminate between content providers? (Yes.)
- What are the welfare effects of allowing consumers to pay to remove advertisements from advertisement-supported products? (Ambiguous, but those watching ads are worse off.)
- Why are some markets characterized by open platforms, extendable by third-parties, and some by closed platforms? (It is a tradeoff between intensified competition and benefits from externalities.)
- Do private platform providers allow third-parties to access their platform when it is socially desirable? (No.)

The answers to these questions are obtained by extending the theoretical literature on two-sided markets.

2 Two-Sided Markets: A Literature Review

On two-sided markets, platforms intermediate transactions between two groups of agents valuing each other's presence. Two-sided markets are common in the telecommunications, media and technology sectors. In the telecommunications sector, mobile phone networks connect callers with receivers of calls, and Internet service providers connect consumers with content providers. In the media sector, broadcasting networks, newspapers and magazines connect consumers with advertisers. In the technology sector, software platforms, such as operating systems and game consoles, connect consumers to application providers and game developers. Examples of two-sided markets are also abundant beyond these sectors. For example, dating services connect men with women, payment systems connect customers with merchants, and shopping malls connect visitors and shopkeepers.

2.1 Seminal Contributions

Despite being common, the literature on two-sided markets is recent. Caillaud and Jullien (2001) and Caillaud and Jullien (2003) analyze price competition between intermediaries on the Internet matching two groups of agents. Their model has two central elements that are now defining the literature on two-sided markets. First, the groups value each other's presence. To increase the chances of finding a match, an agent would like to use the intermediary with the largest number of agents of the other group as customers. This causes indirect network externalities. By joining an intermediary, an agent encourages more agents from the other group to join, which raises the value of the intermediary for her group. Second, intermediaries face a multi-product pricing problem as they can set separate prices to each group. A correct price structure is important to attract both groups. Prices to each group need not reflect the costs of serving that group as cross-subsidization can occur.

While the focus in Caillaud and Jullien (2001) is mostly on the chicken-and-egg problem of attracting both sides in a two-sided market, Rochet and Tirole (2003) analyze the optimal price balance with heterogeneous consumers in the credit card industry. They characterize an optimal price balance with elasticities and show how pricing in two-sided markets relates to pricing in standard markets. They further highlight how common the combination of cross-group externalities and multi-product pricing tends to be in real world markets.

Competition between platforms facing heterogeneous agents is analyzed in Armstrong (2006). He emphasizes how the balance of prices on each side of the market depends on a) the relative sizes of cross-group externalities, b) if prices are fixed or set per transaction and c) if agents single- or multi-home. Multi-homing, as opposed to single-homing, implies that an agent can use multiple platforms simultaneously. Armstrong (2006) also focuses on cross-group externalities varying by side instead of by agent or platform (as in Rochet and Tirole (2003)) and studies lump-sum costs and prices instead of costs and fees set per transaction.

Rochet and Tirole (2006) bring together features from earlier theoretical models and present a canonical model of a two-sided market. They also suggest a definition of what characterizes a two-sided market. If a two-sided market is defined as a market where firms bring together two groups of agents valuing each other's presence, almost any market could be defined as two-sided. Rochet and Tirole (2006) instead propose to focus on price structure. They suggest that a market should be considered to be two-sided if the volume of transactions is affected by a change in the distribution of prices across sides, while the overall price level remains constant.

2.2 A Benchmark Model of a Two-sided Market

Let us consider a version of the canonical model presented in Rochet and Tirole (2006). Two groups of agents, B and S, interact through a monopoly platform. The utility for agent i in group $j \in \{B, S\}$ for $j \neq k$ is

$$u_i^j = A_i^j + (a_i^j - p^j)n^k - P^j. \tag{1}$$

Fees are given by per transaction prices p^j and lump-sum prices P^j. A_i^j denotes the fixed benefits of joining the platform, and a_i^j the marginal benefits of an additional agent of the opposite group joining the platform. Entry is endogenous and the mass of agents on each side, n^j, contains all agents for which $u_i^j \geq 0$ holds. The number of transactions taking place on the platform is the product of the mass of users on each side.

The platform faces the problem of setting prices to maximize

$$\pi = P^B n^B + P^S n^S + (p^B + p^S)n^B n^S. \tag{2}$$

Note that each group cares about the presence of the other group (as long as $a_i^j \neq 0$). The agents also face prices that depend on to which group they belong (P and p depend on j).

Since solving the above pricing problem can be complex, simplifications in the utility structure are common. Caillaud and Jullien (2001) and Caillaud and Jullien (2003) assume homogeneous consumers ($a_i^j = a^j$ and $A_i^j = 0$). Rochet and Tirole (2003) mainly study the case for $P^j = 0$ and $A_i^j = 0$, while Armstrong (2006) emphasizes the case for $p^j = 0$. Some results for the general case are presented in Rochet and Tirole (2006).

Models with $p^j = 0$ and $a_i^j = a^j$ are mainly used in this thesis. Three extensions of the benchmark model are considered. Essay 1 considers optimal regulation of price on one side of the market while allowing the platforms to respond to the regulated price by optimally setting the price on the other side of the market. Essay 2 considers quality discrimination towards one side of the market. Further, one side of the market cares for the number of consumers *not* paying, while the platform simultaneously profits from those who are paying. This makes sense when a media platform allows consumers to pay to remove advertisements. Essays 3 and 4 introduce a new timing structure by allowing platforms to commit to dealing with only one group instead of both groups before competing in price.

Let us now follow Schiff (2007) and derive two central results concerning how prices are determined in a two-sided market. Consider the simplified utility function

$$u_i^j = (a_i^j - p^j)n^k \text{ for } j, k \in \{B, S\} \text{ with } j \neq k. \tag{3}$$

The mass of agents on each side is normalized to unity and a^j is uniformly distributed on $[0, b^j]$. Agent i on side j uses the platform if $a_i^j > p^j$. Demand for the platform on side j is then $n^j(p^j) = \frac{b^j - p^j}{b^j}$. The number of transactions taking place on the platform is the product of the mass of agents on each side using the platform. The platform sets p^B and

p^S to maximize

$$\pi = (p^B + p^S)n^B(p^B)n^S(p^S). \tag{4}$$

The first-order conditions are

$$p^j = \frac{1}{2}(b^j - p^k) \text{ for } j, k \in \{B, S\} \text{ with } j \neq k. \tag{5}$$

The optimal price for one side depends on the price set for the other side. This is because the transaction volume depends on both prices. For the same reason, prices also depend on demand conditions on both sides of the market. Because of this interdependence, prices may be below costs on one side of the market. Losses can be recouped with a high price on the other side. We can also expect both prices to change when demand conditions change on one side of the market. This gives rise to what Rochet and Tirole (2006) calls the "topsy-turvy principle". Factors that tend to increase the price on one side of the market are likely to lower the price on the other side.

2.3 Extensions to the Benchmark Model

The canonical model is useful for studying the price structure in two-sided markets. However, it does not incorporate all aspects of two-sided markets. Since the early contributions, a large number of studies have extended the core model in different directions. Authors have analyzed issues such as intra-side externalities (e.g. Belleflamme and Toulemonde (2007) and Ellison and Fudenberg (2005)), welfare maximizing prices not covering costs (e.g. Jullien (2005) and Bolt and Tieman (2006)), match-quality dependent pricing (Damiano and Li, 2007), exclusivity and vertical integration (e.g. Armstong and Wright (2007) and Hagiu and Lee (2007)), commitments to future price strategies (Hagiu, 2006), different platform ownership structures (e.g. Hagiu (2007b), Economides and Katsamakas (2006) and Nocke, Peitz, and Stahl (2007)) and the difference between matchmakers and platforms (e.g. Hagiu (2007a) and Hagiu and Jullien (2007)). The literature also incorporates business oriented books such as Evans, Hagiu, and Schmalensee (2006) and Evans and Schmalensee (2007), and there are already numerous papers on the antitrust implications of two-sided markets (e.g. Wright (2004) and Evans (2003)). Furthermore, sector-specific studies have emerged.

2.4 Sector-Specific Studies of Two-Sided Markets

2.4.1 Telecommunications

The theory on two-sided markets has been incorporated into telecommunications research on mobile call termination and the Internet.

Mobile telephone operators transport calls between senders and receivers of calls, each valuing the presence of the other. They also set the fee for outgoing and incoming calls. As compared to earlier studies such as Gans and King (2000), Armstrong (2002) or Wright (2002), Armstrong (2006) analyzes a two-sided market bottleneck model where callers multi-home (they can call any network) and receivers of calls single-home (they can only receive a call through their own operator). He emphasizes that there is no competition in the market for terminating calls. Operators are free to set the price for termination at the monopoly level. Valletti (2006) and Hausman and Wright (2006) also echo the importance of a two-sided market perspective. Valletti (2006) discusses policy and regulatory implications of this view. Hausman and Wright (2006) present a two-sided market model incorporating the substitutability between mobile phone calls and fixed line calls.

Similar to mobile telephone operators, Internet backbone networks transport data from senders to receivers. They set different fees for incoming and outgoing data. Laffont, Scott, Rey, and Tirole (2003) study competition on the Internet backbone. The general economics of the Internet backbone is discussed in Economides (2003), while Foros, Kind, and Sorgard (2002) and Foros, Kind, and Sorgard (2006) discuss issues in relation to regional versus global networks. Hermalin and Katz (2004) study if the sender or the receiver should pay for the exchange of an electronic message and Hermalin and Katz (2007) study product line restrictions related to transmission speeds on the Internet.

Essay 1 emphasizes the importance of a two-sided market perspective in understanding central aspects of the Internet. Internet Service Providers can be seen as facilitating transactions between consumers and content providers. They also set the subscription price to consumers and have the power to set a price to content providers for delivering content to consumers. The essay analyzes if, within a two-sided market framework, a regulatory requirement of a zero price to content providers is socially desirable.

2.4.2 Media

A two-sided market perspective to media markets brings into focus the role of media companies as platforms intermediating the information between consumers and advertisers.

Anderson and Coate (2005) study broadcasting from a two-sided market perspective. This approach allows them to consider the role of a media platform in both providing quality programming and allowing advertisers to reach consumers. The endogeneity of advertising quantity is an important departure from earlier literature taking advertising prices and quantity as given (e.g. Steiner (1952), Spence and Owen (1977) and Doyle (1998)). This approach has become rather popular since then: see, for example, Gabszewicz and Laussel (2004), Choi (2006a), Crampes, Haritchabalet, and Jullien (2006), Peitz and Valletti (2005), Kind, Nilssen, and Sorgard (2007) and Anderson and Gabszewicz (2006).

Continuing on the theme of endogenous advertising quantity, Essay 2 analyzes if media platforms have incentives to allow consumers to pay to remove advertisements from an otherwise advertisement-free product. If so, what are the welfare implications of this strategy?

2.4.3 Technology

Apart from intermediaries on the Internet, two-sided market research relating to the technology sector has mainly focused on video game consoles and software platforms. Hagiu (2006) considers commitment and pricing for two-sided platforms. He analyzes situations where one side must be signed up before the other. This makes sense for video game platforms. A video game console needs to have some games available when it is launched, so that console manufacturers often commit to a price for the video game console before it is launched. Lee (2007) also analyzes video games but focuses on vertical integration and exclusivity.

Choi (2006b) examines a two-sided market model with tying and multi-homing (relating to the antitrust case of Microsoft tying the Media Player with Windows). He shows that tying may improve welfare when multi-homing is possible. Tying induces more multi-homing and makes content that is specific to a platform available to more users. In a related paper, motivated by the Time Warner and AOL merger, Doganoglu and Wright (2006) ask if multi-homing can be a substitute for compatibility between platforms. They find that it may not, since multi-homing reduces price competition and introduces costs not internalized by the firms. Schiff (2003) discusses compatibility between platforms in two-sided markets. He shows that duopoly with compatibility is socially preferable to monopoly or duopoly without compatibility.

Essays 3 and 4 analyze open versus closed platforms from a two-sided market perspective. An open platform allows for the development of third-party applications. A closed one does not. Essay 3 studies why some industries are characterized by open and some by closed platforms. Essay 4 analyzes whether private platforms have socially efficient incentives to provide open platforms.

2.5 Summary

The literature on two-sided markets is fairly recent, but several studies have already been published. The literature has focused on two central issues: how should a platform set prices to get both sides of the market on board and what characterizes the optimal price balance? In the telecommunications sector, two-sided market theory has been applied to study mobile call termination and the Internet. In the media sector, it has spurred analyses of the role of media firms in bringing together consumers with advertisers. In the technology sector, the research is on intermediaries on the Internet, software platforms and video game consoles. The essays in this thesis contribute research on two-sided markets in these sectors.

3 The Essays: Summaries and Main Results

3.1 Essay 1: Net Neutrality on the Internet: A Two-sided Market Analysis

The Internet is the primary global network for digital communications. It allows for the provision of a number of different services to consumers (such as e-mail, information services, peer-to-peer services and Internet telephony). Since the inception of the Internet, information packets have been transported on the Internet under net neutrality. This regime does not distinguish in terms of price between bits or packets depending on the services for which they are used. Neither does it distinguish in price based on the identities of the uploader and downloader. As video services and digital distribution of content over the Internet are growing, Internet service providers such as AT&T and Verizon in the Unites States have recently required additional compensation from content companies such as Google, Yahoo and Microsoft for carrying valuable digital services. If they were granted this, it would be a sharp departure from the net neutrality regime. This has started an intense debate on the underlying structure of the Internet and how communication companies operating the network should be regulated.

This essay asks if a regulatory requirement of a zero price to content providers (implied by net neutrality) is socially desirable. The analysis suggests the answer to be yes. The benefits of net neutrality regulation are discussed in the context of a two-sided market model where platforms sell Internet access services to consumers and may set fees to content and applications providers on the other side of the Internet. When access is monopolized, net neutrality regulation (zero fees on the other side of the market) generally increases the total industry surplus as compared to the optimal monopoly price structure at which fees to content and application providers are positive. Similarly, imposing net neutrality in duopoly increases the total surplus as compared to duopoly competition between platforms charging positive fees to content providers. The article also discusses how price and non-price discrimination strategies may be used once net neutrality has been abolished and how the results generalize to other two-sided markets.

3.2 Essay 2: Paying to Remove Advertisements

Casual observation suggests that Internet media firms sometimes allow consumers to pay to remove advertisements from an advertisement-based product. This essay characterizes when the business model is optimal for a monopolist and analyzes the effect on advertising quantity and surplus distribution. Within a two-sided market framework, the essay asks the following question: What are the welfare effects of allowing consumers to pay to remove advertisements from an otherwise advertisement supported product? The question is relevant as traditionally, the provision of programming and advertising in the broadcasting industry has been subject to a considerable degree of attention from regulators. For example, advertising quantity is regulated in several European countries. As new business strategies become available, it is important that regulation and policy keep up with changes in the industry.

The essay finds that the optimality of the business model depends on the relation between product quality, the annoyance of advertisements and advertisers' profit margins. When consumers can pay to remove advertisements, there is an increase in advertisement quantity and the firm and the advertisers gain at the consumers' expense. Advertising quantity and firm profits may be increasing in the annoyance of advertisements. The effect on total welfare is ambiguous.

3.3 Essay 3: Open Versus Closed Platforms

Why are some platforms open to third-party development while others are closed? This choice is highly relevant in a number of markets. For example, operating systems for modern personal computers are generally open. Apple's OS X, Microsoft's Windows Vista and various versions of Linux all allow for, and encourage, application development. The same holds for video game consoles. As of 2008, the three large consoles on the market (the Xbox360, Playstation 3 and the Wii) are all sold as open platforms with third-parties developing games for the consoles. In contrast, there also exists a sea of cheaper closed consoles that come with one or several games pre-installed (such as Sudoku or Tetris).

In some markets, the same firm might provide both open and closed platforms. For example, high-end phones usually come installed with an open operating system that allows for third-party application development. The Nokia N95 comes with the S60 software that permits users to install software from third-party application developers. Cheaper mobile phones, such as the Nokia 1600, are often closed.

Interestingly, when Apple entered the mobile phone market in June 2007 with the iPhone, they entered with a closed platform. Native third-party application development was impossible for the phone, thus upsetting developers that had become used to open high-end phones. However, Apple has announced that third-party application development will be possible for the iPhone in June 2008.[1]

This essay builds on the existing literature on two-sided markets by endogenizing the choice of operating in a one-sided (closed) or a two-sided (open) market. The main result of the study is that the choice may involve a tradeoff between benefits from an open platform on the one hand and intensified competition for consumers on the other. Providing an open platform is beneficial because the platform will be of higher value to consumers when third-parties have access to the platform. The platform can also profit from selling access to consumers to third-parties. But because opening the platform makes the rival more aggressive in pricing, platform providers may unilaterally prefer to commit to keep their platforms closed instead of open.

[1] http://www.apple.com/pr/library/2008/03/06iphone.html. Accessed August 2008.

3.4 Essay 4: Efficiency and the Provision of Open Platforms

Do private firms allow third-parties to access their platform or develop extensions for their product when it is socially desirable? This question has repeatedly been a concern for anti-trust authorities. For example, in 1955, the FCC in the United States agreed with the AT&T Bell System that an add-on to AT&T phones (the Hush-A-Phone) that helped reduce noise could not be marketed and sold independently since it was a "foreign attachment" to the AT&T network. The FCC also concluded that all telephone equipment should be sold by the network operator. This decision was, however, overturned on appeal by the D.C. Circuit.[2] In line with this appeal, the FCC later (in 1968) ruled that it should be possible to use another attachment marketed by an independent firm, the Carterfone, on the AT&T Bell System network. Another example is the anti-trust case Eastern Kodak Co. v. Image Technical Services, Inc [3]. Kodak had excluded third-parties from being able to service the equipment they had sold. However, the Supreme Court ruled that external firms should be able to service Kodak's equipment.

This essay takes a two-sided market approach and proposes two new reasons why private incentives may be insufficient.

First, a private firm may not be able to internalize all benefits from cross-group externalities arising when third-parties are involved since perfect price discrimination may not always be possible. Part of the increase in the value of the platform coming from third-parties will go to consumers. Some value of having access to consumers through the platform will go to third-parties. A private platform does not account for this value and thus, it will have too low incentives to provide an open platform as compared to the social optimum accounting for consumer surplus and third-party profits.

Second, firms may have strategic incentives to shut out producers of third-party extensions because it relaxes the competition for consumers. When open platforms compete for consumers, reducing the price to consumers does not only win more consumers but also attracts more third-parties to the platform (since more consumers can now be reached through the platform). The incentives to cut prices are then stronger when the platforms are open as compared to when they are closed. If allowed to commit to providing a closed platform, firms may have unilateral incentives to keep their platforms closed to avoid intensified competition. This may be the case even when the social optimum involves open platforms.

Based on these two findings, the analysis suggests a policy in support of open platforms.

4 A Summary and Beyond

This thesis extends the existing literature on two-sided markets to cover current issues on business strategies, policy and regulation in the telecommunications, media and technology sectors. From a theory perspective, a standard two-sided market model is extended to

[2]Hush-A-Phone Corp., 20 .F.C.C. 391, 420 (1955) (Decision), rev'd, 238 F2.d 266 (D.C. Cir. 1956)

[3]Eastern Kodak Co. v. Image Tech Services, 125 F3d. 1995 Ninth Circuit, 1997

cover a) quality discrimination on one side of the market, b) optimal regulation of the price on one side in a two-sided market and c) the choice between offering a one-sided (closed) or a two-sided (open) platform. In the context of telecommunications, Essay 1 discusses net neutrality regulation. In relation to the media sector, the strategy of allowing consumers to pay to remove advertisements from an otherwise ad-supported product is discussed. Relating to the technology sector, the thesis analyzes the choice of supplying a closed or an open platform and whether private and social incentives to provide an open platform coincide.

The issues studied here are likely to continue to attract attention from scholars. In telecommunications, the issue of net neutrality is a high-level question with large groups of supporters on both sides. Further, the economics behind the issue does not yet give a clear view on whether net neutrality is a good or bad policy. In media, increased customization of content and targeting of advertisements is likely to lead to more studies on how consumers and companies are affected. Finally, the technology industry is dominated by firms operating as platforms in two-sided markets. Two-sided market theory on software platforms and online intermediaries is therefore likely to develop rather intensively.

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List of Essays

Part II

The Essays

Net Neutrality on the Internet: A Two-sided Market Analysis*

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Abstract

We discuss net neutrality regulation in the context of a *two-sided market* model where platforms sell Internet access services to consumers and may set fees to content- and application providers "on the other side" of the Internet. When access is monopolized, we find that for reasonable parameter ranges, net neutrality regulation (that imposes zero fees "on the other side" of the market) increases the total industry surplus as compared to the fully private optimum at which the monopoly platform imposes positive fees on content- and application providers. Similarly, we find that imposing net neutrality in duopoly increases the total surplus as compared to duopoly competition between platforms that charge content providers positive fees. We also discuss the incentives of duopolists to collude in setting the fees "on the other side" of the Internet while competing for selling Internet access to customers and how price and non-price discrimination strategies may be used once net neutrality has been abolished.

Key words: net neutrality, two-sided markets, Internet, monopoly, duopoly, regulation, discrimination

JEL Classification: L1, D4, L12, L13, C63, D42, D43

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1. Introduction

The Internet is the primary global network for digital communications. A number of different services are provided on the Internet, including e-mail, browsing (using Internet Explorer, Firefox, Opera or other browsers), peer-to-peer services, Internet telephony (Voice over Internet Protocol "VOIP"), and many others. A number of different functions/applications run on top of the Internet browser, including information services (Google, Yahoo, MSN), display of images, transmission of video and other features. Since the inception of the Internet, information packets are transported on the Internet under "net neutrality". This is a regime that does not distinguish in terms of price between bits or packets depending on the services for which these bits and packets are used or based on the identities of the uploader and downloader.

As video services and digital distribution of content over the Internet are growing, Internet broadband access providers AT&T, Verizon and a number of cable TV companies have recently demanded additional compensation for carrying valuable digital services. Ed Whitacre, AT&T's CEO, was recently quoted in *BusinessWeek* referring to AT&T's Internet infrastructure: "Now what they would like to do is use my pipes free, but I ain't going to let them do that because we have spent this capital and we have to have a return on it." [1] Naturally, no one is using the Internet for free, since both sides of an Internet transfer pay.[2] AT&T's president, together with Verizon and cable TV companies, are asking for the abolition of "net neutrality." AT&T and Verizon and some cable companies would like to abolish the regime of net neutrality and substitute it with a pricing schedule where, besides the basic service for transmission of bits, there will be additional charges by the Internet operator for services applied to the originating party (such as Google, Yahoo or MSN). The access network operators have also reserved the right to have different charges based on the identity of the provider even for the same type of packets, for example to be able to charge Google more than Yahoo for the same transmission.

In abolishing net neutrality, telephone and cable companies are departing from the "end-to-end principle" that has governed the Internet since its inception.[3] Under the end-to-end principle, computers attached to the Internet that are sending and receiving information packets did not need to know the structure of the network and could just interact end-to-end. Thus, there could be innovation "at the edge" of the network without interference from network operators.[4] The way the Internet has operated so far is a radical departure from the operating principles of the traditional

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[1] Interview with Ed Whitacre, *BusinessWeek* November 7, 2005.

Q. How concerned are you about Internet upstarts like Google (GOOG), MSN, Vonage, and others?

A. How do you think they're going to get to customers? Through a broadband pipe. Cable companies have them. We have them. Now what they would like to do is use my pipes free, but I ain't going to let them do that because we have spent this capital and we have to have a return on it. So there's going to have to be some mechanism for these people who use these pipes to pay for the portion they're using. Why should they be allowed to use my pipes?
The Internet can't be free in that sense, because we and the cable companies have made an investment and for a Google or Yahoo! (YHOO) or Vonage or anybody to expect to use these pipes [for] free is nuts!

[2] See Economides (2008).

[3] For more on the end-to-end argument, see e.g. Saltzer, Reed and Clark (1984).

[4] See Cerf (2006a, b) for a detailed explanation of this argument.

digital electronic networks predating it, such as Compuserve, Prodigy, AOL, AT&T Mail, MCI Mail and others. These older electronic networks were centralized with very little functionality allowed at the edge of the network.

From an economics point of view, the departure from net neutrality regulation will have six consequences. First, it will introduce *two-sided pricing* on the Internet where a transmission company controlling some part of the Internet (here *last mile access*) will charge a fee to content- or application firms "on the other side" of the network which typically did not have a contractual relationship with it. Second, it will introduce prioritization, which may enhance the arrival time of information packets originating from paying content- and application firms "on the other side," and may degrade the arrival time of information packets that originate from non-paying firms. In fact, the present plans of access providers are to create a "special lane" for information packets of paying firms while restricting the lane for non-payers without expanding total capacity. By manipulating the size of the paying firms' lane, the access provider can guarantee a difference in the arrival rates of packets originating from paying and non-paying firms, even if the actual improvement in arrival time for paying firms' packets is not improved as compared to the case of net neutrality. Third, if access providers choose to engage in identity-based discrimination, they can determine which of the firms in an industry sector on the other side of the network, say in search, will get priority and therefore win. This can easily be done by announcing that prioritization will be offered to only one of the search firms, for example the one with the highest bid. Thus, determining the winner in search markets and other markets "on the other side" will be in hands of access providers. This can create very significant distortions since it seems reasonable to assume that the surplus "on the other side" of the Internet is a large multiple of the combined telecom and cable TV revenue from residential Internet access.[5] Fourth, new firms with small capitalization (or those innovative firms that have not yet achieved a significant penetration and revenues) will very likely not be the winners of the prioritization auction. This might reduce innovation. Fifth, access networks might favor their own content and applications rather that those of independent firms. Finally, since the Internet consists of a series of interconnected networks, any of these networks, and not just the final consumer access network, can, in principle, ask content and application providers for a fee. This can result in multiple fees charged for a single transmission and lead to a significant reduction in trade on the Internet, [6] similar to the reduction of trade in medieval times when the weakening of the state power of the Roman Empire allowed multiple fees to be collected by many independent city powers along a trading route.

In this paper, we primarily deal with the first issue in the previous paragraph by formally building a model of a two-sided market. We explicitly model the Internet

[5] See Economides (2008) for a more detailed discussion of this issue.

[6] The imposition of multiple margins by independent producers of complementary goods was first discussed by Cournot (1838). In Cournot's setup, there are two complementary components that can be combined in fixed proportions to produce a composite good. In the setup, each component is produced by a single firm, *i.e.* we have two independent monopolists. In a second setup, both components are produced by the same firm (integrated monopoly). He showed that the price of the composite good will be higher with independent monopolists than with integrated monopoly. This is because each of the independent monopolists does not take fully into account the effect of his price increase on the market. This has been called "double marginalization."

broadband market as a two-sided network consisting of broadband users on one side and content and applications providers on the other. Prices imposed on both sides have direct implications for the number of broadband consumers as well as the number of active providers of content and applications. In our framework, Net neutrality is defined as a restriction that Internet Service providers cannot directly charge content providers for access to consumers, i.e. the price on one side of the market is constrained to zero. This is a direct consequence of the fact that net neutrality would prohibit Internet service providers from inspecting packets to determine from where they originate. If they cannot tell packets apart, they cannot charge content providers for access to consumers, since they do not know whom to charge. Note that we only consider direct charges over and above charges for sending and receiving traffic from the Internet backbone.

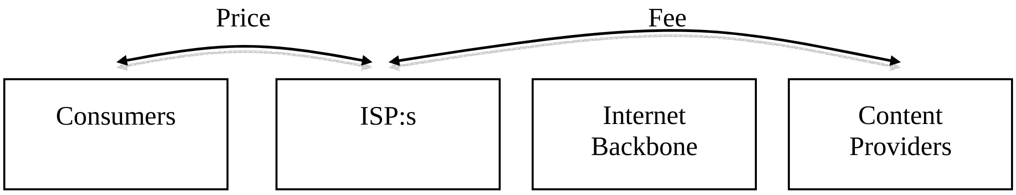

Figure 1: **We take the Internet Backbone as passive and only consider the price for Internet access that consumers pay and possible direct fees imposed on content providers by ISP:s. These fees are made possible if net neutrality is abolished as the ISP can then determine the origins of packets it delivers to consumers.**

We discuss the incentives of a monopoly broadband Internet access network, starting from net neutrality, to initiate a positive fee to the content- and applications side of the market, besides the price it charges to users/subscribers. We show that while a monopoly broadband Internet access network has an incentive to charge a positive fee to content providers, for a reasonable parameter range and when the monopolist would like to charge content providers, an increase in such a fee above zero decreases the total surplus. In fact, it is total surplus maximizing for the platform to subsidize content providers. This is not surprising given the two-sided nature of the Internet market. We further show that in general, net neutrality increases the total surplus as compared to duopoly competition between platforms that would impose positive fees on content providers. The reason is the surplus loss arising when some content providers choose to remain inactive when fees are positive.

Despite a considerable literature discussing the rights and legal issues of net neutrality and its abolition, the literature on economic analysis of this issue is thin. Three papers have emerged in relation to the second issue above, i.e. the prioritization of information packets. In a paper relating to the establishment of multiple "lanes" or quality options for application providers, Hermalin and Katz (2007) analyze a model where net neutrality is equivalent to a single product (quality) requirement. The effect of restricting the product-line is that low valuation application providers become excluded, medium valuation providers purchase higher and more efficient qualities and high valuation application providers purchase a lower valuation and less efficient qualities. The impact on total surplus is ambiguous, but the set of applications available is reduced.[7] Focusing on congestion, Cheng, Bandyopadhyay and Guo

[7] Hermalin and Katz (2007) do not address the issue of the reduction of the "standard" lane for Internet access that is likely to reduce consumers' welfare.

(2007) model two content providers who can avoid congestion by paying ISPs for preferential access.[8] They find that abolishing net neutrality will benefit ISPs and hurt content providers. Depending on the parameter values, consumers are either unaffected or better off. Social welfare increases when net neutrality is abandoned and one content provider pays for access but remains unchanged when both content providers pay. The reason why the consumer surplus may increase is that it is always the more profitable content provider that pays for access and hence, gets preferential treatment. This benefits consumers of the more profitable content provider because congestion is reduced. However, it means a loss for consumers of the less profitable content provider that does not pay for preferential access, since there is an increase in the congestion costs. They also find that the incentives for the broadband provider to expand its capacity are higher under net neutrality regulation since more capacity leads to less congestion. Since congestion decreases, Internet services become more valuable (to the benefit of ISPs). If net neutrality is abolished, their model predicts reduced investment incentives due to congestion becoming less of a problem.

Choi and Kim (2007) study both a static and a dynamic setting focusing on how innovation incentives are affected by net neutrality. They find ambiguous results regarding the impact of net neutrality regulations on welfare, but highlight that in a dynamic setting, net neutrality regulation affects the incentives of the network operator by either allowing the network operator to charge more/less for access or by allowing the network operator to sell rights to prioritized delivery of content. Concerning content providers, the authors find that since the network operator can extract returns from investments through selling first priority access to consumers, content providers may have stronger investment incentives under net neutrality regulation. However, it is not clear that the network operator wishes to extract all returns on potential investments since he has incentives to encourage some investment by content providers.[9]

In contrast to the above literature, we focus on the issue of two-sided pricing made possible by the abolishment of net neutrality regulation. Hence, our paper is closely related to the literature on two-sided markets (e.g. Armstrong (2006), Caillaud

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[8] See also Jamison and Hauge (2007).

[9] In addition, Chen and Nalebuff (2007) analyze competition between complements and briefly touch upon the issue of net neutrality. Some services that are offered by an ISP may also be offered over the Internet (such as Vonage or Skype). There is a concern that the ISP would like to disrupt the quality of the services of its competitors to further its own product. However, the authors show that this would not be profit maximizing in their model since a monopolist ISP benefits from valuable complements such as VOIP services (a higher price for internet access could be charged instead of trying to force consumers to its own VOIP service). Hogendorn (2007) analyzes the differences between open access and net neutrality and emphasizes that these are different policies that may have different implications. Hogendorn interprets net neutrality in a slightly different way than most of the literature. Open access refers to allowing intermediaries access to conduits (so that intermediaries such as Yahoo can access conduits like AT&T at a nondiscriminatory price), while net neutrality is interpreted to mean that content providers have unrestricted access to intermediaries (so that Yahoo cannot restrict which content providers can be reached through its portal). Under net neutrality, a smaller number of intermediaries enter the market due to decreased profits. Open access, on the other hand, increases the entry of intermediaries since they now have free access to conduits. In general, Hogendorn finds that open access is not a substitute for net neutrality regulation. Finally, Economides (2008) discusses several possible price discrimination strategies that may become available if network neutrality is abolished. He presents a brief model showing that the total surplus may be lower when the platform imposes a positive fee on an application developed for it due to the fact that the fee raises the marginal cost of the application and hence, also its price.

and Jullien (2003), Hagiu (2006) and Rochet and Tirole (2003, 2006)). In particular, we build on the approach in Armstrong (2006). Related is also Hagiu (2007) who discusses open versus proprietary platforms, where open platforms imply zero prices on each side of the market. In contrast, we allow one price to be positive while the other is constrained to zero under net neutrality regulation.

We have structured our paper in the following way. We first present and evaluate the impact of net neutrality regulation in a monopoly model in section 2. In section 3, we extend the monopoly model to a duopoly setting with multi-homing content providers. The paper is concluded in section 4.

2. Platform Monopoly

We start with a platform monopoly model of a two-sided market. A platform (say a telephone company, such as AT&T) sells broadband Internet access to consumers at a subscription price p and possibly collects a fee s from each content or application provider to allow the content to reach the consumer. We assume that the platform monopolist (and later in the paper, duopolists) only offers linear fee contracts, *i.e.*, it does not offer quantity discounts and does not offer take-it-or-leave-it contracts with lump-sum fees. Furthermore, we abstract from the full complexity of the Internet, which consists of many interconnected networks and assume that the networks that lie between the access provider and the content provider are passive (see figure 1).[10] Finally, we assume that the cost of providing the platform service is c per consumer.

2.1 Consumers

Consumers are interested in accessing the Internet to reach search engines (e.g. Google), online stores (e.g. Amazon), online auctions (e.g. eBay) and online video, audio, still pictures, and other content. Consumers are differentiated in their preferences for Internet access. A consumer i's location (type) x_i indexes his/her preference for the Internet, so that consumers with a lower index place a higher value on the service. Consumers pay a transportation cost equal to t per unit of distance "traveled".[11] We assume these to be uniformly distributed on the interval $x \in [0,1]$ with the platform located at $x = 0$ (this specification allows for an easy extension to a duopoly setting; see the appendix for a discussion of the case where the platform is located at the center of the interval). Consumer i's utility is specified as

$$u_i = v + bn_{cp} - tx_i - p \tag{1}$$

where $v > c$ is an intrinsic value that a consumer receives from connecting to the Internet irrespective of the amount of content,[12] b is the marginal value that a

[10] As noted earlier, if the *in-between* networks also attempted to charge a fee to content providers, there would be the possibility of high prices because of double or multiple marginalization.
[11] Assume that the market is not covered and demand is differentiable.

[12] Such benefit may arise from Internet-enabled services that do not crucially depend on the number of other Internet subscribers or availability of content. An example may be television services bundled

consumer places on an additional content provider on the Internet and n_{cp} is the number of content providers that are active.

2.2 Content Providers

Content providers rely on advertising revenue per consumer, a, to generate revenue. We assume content providers to be uniformly distributed on the unit interval and have a unit mass. We make the simplifying assumption that content providers are independent monopolists, each in its own market, and therefore do not compete with each other. Each content provider then earns an_c, where n_c is the number of consumers paying the platform for access to content providers. Thus, a is the value for a content provider of an additional consumer connected to the Internet.

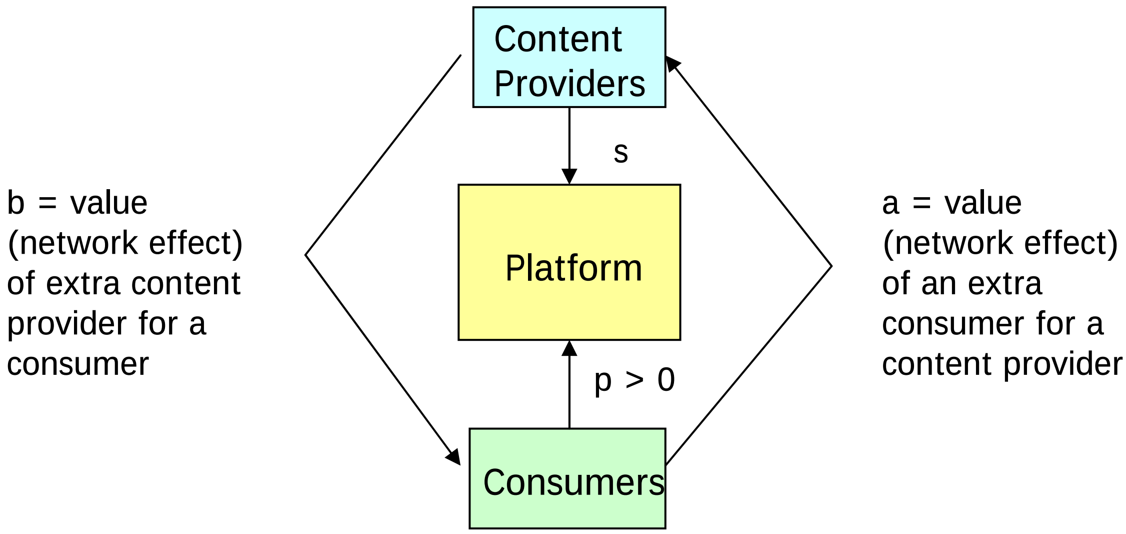

Figure 2: Interaction of consumers with content providers and vice versa through the platform.

Content providers are heterogeneous in terms of the fixed costs of coming up with a business idea and setting up their business. A content provider indexed by j faces a fixed cost of fy_j, where y_j is the index of the content provider's location on the unit interval.[13] The marginal costs for serving advertisements to consumers are taken to be zero.[14] Each content provider may have to pay the platform a lump-sum fee equal to s to gain access to users. This fee is assumed to be the same for all content providers and it is set by the platform. Thus, a content provider j's profit is[15]

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with Internet access.

[13] We assume that the "market is not covered" in the sense that some content providers will always have such high fixed costs that they decide not to enter the market. Further, we assume demand for access to consumers to be differentiable.

[14] See Appendix B for a discussion on how positive marginal costs on the content provider side affect our results.

[15] Alternatively, the fee to the platform can be specified to be proportional to the number of platform customers, $\pi_j = an_c - sn_c - fy_j$. The qualitative results of our main specification go through in this alternative specification.

$$\pi_j = an_c - s - fy_j \,. \tag{2}$$

Net neutrality regulation equals the case where s is zero. Figure 2 shows the interaction between consumers and content providers through the platform.

2.3 Demand

In this two-sided market, the demand for content depends on the expected amount of content provided since more consumers will connect to the network if more expected content is available. In addition, the provision of content depends on the expected number of consumers. That is, when the expected number of consumers is n_c^e and the expected number of content providers is n_{cp}^e, the marginal consumer, x_i, who is indifferent between subscribing to the Internet and remaining outside, is

$$x_i = n_c = \frac{v + bn_{cp}^e - p}{t}, \tag{3}$$

while the marginal content firm, y_i, which is indifferent between being active and remaining outside the market, is

$$y_i = n_{cp} = \frac{an_c^e - s}{f}. \tag{4}$$

Each side of the market correctly anticipates its influence on the demand of the other side and therefore, $n_c^e = n_c$ and $n_{cp}^e = n_{cp}$. Thus, the number of consumers and active content providers is given by the solution to the simultaneous equation system (3) and (4), which is

$$n_c(p,s) = \frac{f(v-p) - bs}{ft - ab} \quad \text{and} \quad n_{cp}(p,s) = \frac{a(v-p) - ts}{ft - ab}. \tag{5, 6}$$ [16]

2.4 Monopoly Platform Optimum

Consider first the monopoly platform private optimum under which the platform is free to set both the subscription price p and the fee to content providers s. The platform faces the problem of choosing p and s to maximize

$$\Pi(p,s) = (p-c)n_c(p,s) + sn_{cp}(p,s). \tag{7}$$

Because the two markets provide complementary products, the monopolist finds an inverse relationship between p and s; that is, maximizing with respect to p results in a smaller p when s is larger, and maximizing with respect to s results in a smaller s when p is larger. Specifically, the optimal p for the monopolist given s,

[16] We check later to ensure that under our assumptions, $n_c \in [0,1]$ and $n_{cp} \in [0,1]$ in equilibrium.

defined by $\frac{\partial \Pi}{\partial p} = 0$, is given by

$$p(s) = \frac{f(v+c) - (a+b)s}{2f}, \qquad (8)$$

and the optimal s for the monopolist given p, defined by $\frac{\partial \Pi}{\partial s} = 0$, is

$$s(p) = \frac{av + bc - (a+b)p}{2t}. \qquad (9)$$

Solving the two above equations simultaneously gives the consumers' subscription price and the fee charged to the content providers that maximize the platform's profits:[17,18]

$$p^M = \frac{(2ft - ab)(v+c) - b^2c - a^2v}{4ft - (a+b)^2} \text{ and } s^M = \frac{(a-b)f(v-c)}{4ft-(a+b)^2}. \qquad (10, 11)$$

Superscript *M* indicates the fully private optimum where both p and s are chosen by the monopoly platform. The participation levels are:

$$n_c^M = \frac{2f(v-c)}{4ft-(a+b)^2} \text{ and } n_{cp}^M = \frac{(a+b)(v-c)}{4ft-(a+b)^2},^{19} \qquad (12)$$

and the profits of the monopoly platform are

$$\Pi^M = \frac{f(v-c)^2}{4ft-(a+b)^2}. \qquad (13)$$

The platform benefits from additional content (since additional content increases the willingness to pay of its subscribers) but does not receive the full benefit of the content increase. Therefore, the platform cannot fully internalize the network effects of content and charges a positive price to content providers. The platform service provider sets a positive fee to content providers for accessing users if $a > b$. This means that if content providers value additional consumers more highly than consumers value additional content providers, the platform will charge content providers a positive price for accessing consumers. It may be argued that consumers

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[17] To satisfy the second-order conditions, $-\frac{2f}{(ft-ab)} < 0$ and $\frac{4ft-(a+b)^2}{(ft-ab)^2} > 0$, we need to assume that $4ft-(a+b)^2 > 0$.

[18] Since $p^M - c = \frac{(v-c)(2ft-ab-a^2)}{4ft-(a+b)^2} > 0$, the price consumers pay, p^M, is above the marginal cost if $2ft - a(a+b) > 0$ and above 0 if $2ft(v+c) - (a+b)(av+bc) > 0$. Although a negative price might not be implementable, the platform may tie other products with the offer for Internet access and thereby, in effect, obtain a negative price. See Amelio and Jullien (2007).

[19] To ensure that the market is not covered on either side, we impose $4ft-(a+b)^2 - (a+b)(v-c) > 0$ and $4ft-(a+b)^2 - 2f(v-c) > 0$, *i.e.*, that the differentiation parameters *f* and *t* are sufficiently high.

have become more valuable to content providers lately, so that there are higher incentives for a platform, such as AT&T, to seek ways of being able to charge content providers for access to users. In some other networks, for example in the network of a game platform/console (such as the Sony PlayStation platform) and games (software), the platform similarly collects a fee from independent game developers.

In what follows, and to allow us to focus on the case where a private profit-maximizing platform wants to charge content providers a positive price, we assume that content providers value consumers more than consumers value content providers. An alternative interpretation is that more surplus from the interaction between consumers and content providers is created on the content provider side of the market.

Assumption 1: $a-b>0$

It is worth noting that in some two-sided markets, a firm on the other side of the market may value an additional platform consumer less than a platform consumer values an additional firm on the other side of the market, that is, $a < b$. For example, a Windows application (not sold by Microsoft) may value an additional Windows purchaser less than this consumer values the existence of this additional application. When this is true, the platform will subsidize the firms on other side of the market to increase their number and more fully internalize the externality. Thus, operating system companies typically subsidize developers of applications by embedding subroutines that are valuable to application developers in the operating systems, but not directly valuable to users.[20] [21] Another example is the interaction among a credit card platform network (such as VISA), a credit card issuing bank and consumers. Some consumers who pay their monthly balances in full are effectively subsidized by the issuing banks by receiving airline miles and other perks while the issuers collect fees from the merchants. In this case, the value of an additional consumer to the issuing bank exceeds the value of an additional issuing bank to a consumer, *i.e.*, b > a.[22] Thus, in summary, we have shown that:

Proposition 1: An unconstrained profit-maximizing platform charges a positive fee to the other side of the market if and only if content providers value additional consumers more highly than consumers value additional content providers.

Note from the above that for the second-order conditions to hold, we need an assumption on the relation between *f,t,a* and *b*. For the second-order condition above (and those below), we need to assume

Assumption 2: $ft-(a+b)^2>0$.

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[20] See also Economides and Katsamakas (2006a, b) for a deeper discussion of this issue and a contrast with practices in open source operating systems.

[21] Also note that in some two-sided markets, the organizing networks have arbitrarily set the fee between different network firms without allowing the market to set a positive or negative fee across them according to specific circumstances. This is the case in the Visa and MasterCard networks of acquiring and issuing banks. These networks have set a fixed percentage fee between an acquiring and an issuing bank on the dollar value of transactions without regard to the specific market position of each pair of such banks. See Economides (2007) and Rochet and Tirole (2003).

[22] In this case, we place the consumers at the top of Figure 1 and the credit card issuing banks at the bottom.

This assumption states that the transportation costs and the fixed costs on the content provider side are sufficiently large in relation to consumers and content providers' valuation of each other.

2.5 Monopoly under Network Neutrality Regulation

Now consider the optimal choices of the monopoly platform provider under net neutrality regulation, that is, when, by regulation, $s = 0$. The objective of the platform is now to maximize

$$\Pi^{NN} = (p - c)n_c , \tag{14}$$

which gives the equilibrium price $p^{NN} = \frac{v+c}{2}$.[23] Equilibrium participation levels are

$$n_c^{NN} = \frac{f(v-c)}{2(ft-ab)} \text{ and } n_{cp}^{NN} = \frac{a(v-c)}{2(ft-ab)}, \tag{15, 16}$$

and platform profits are

$$\Pi^{NN} = \frac{f(v-c)^2}{4(ft-ab)}. \tag{17}$$

2.6 Social Optimum

We now solve for prices p and s that maximize the total surplus defined as

$$TS(p,s) = \Pi(p,s) + CS_c(p,s) + \Pi_{cp}(p,s), \tag{18}$$

where $\Pi(p,s)$ are platform profits,

$$CS_c(p,s) = \int_0^{n_c(p,s)} (v + bn_{cp}(p,s) - tx - p)dx \tag{19}$$

is consumer surplus and

$$\Pi_{cp} = \int_0^{n_{cp}(p,s)} (an_c(p,s) - fy - s)dy, \tag{20}$$

is the sum of the content providers' profits.

Maximizing the total surplus,[24] a planner chooses

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[23] The second-order condition $-\frac{2f}{ft-ab} < 0$ is satisfied if $ft - ab > 0$. In addition, we need to impose that $2(ft-ab) - f(v-c) > 0$ and $2(ft-ab) - a(v-c) > 0$ to ensure that the markets are not covered.

$$p^* = \frac{ftc - b(a+b)c - a(a+b)v}{ft-(a+b)^2} < c \text{ and } s^* = -\frac{bf(v-c)}{ft-(a+b)^2} < 0 .^{25\ 26} \tag{21}$$

This results in maximized total surplus

$$TS(p^*, s^*) = \frac{f(v-c)^2}{2(ft-(a+b)^2)}. \tag{22}$$

<u>Proposition 2a</u>: A total surplus maximizing planner/regulator in the two-sided market with network effects chooses below-cost pricing in both markets.

<u>Proposition 2b</u>: A total surplus maximizing planner/regulator in a two-sided market with network effects constrained to marginal cost pricing in the subscription market chooses below-cost pricing in the content market.[27]

<u>Proposition 2c</u>: A total surplus maximizing planner/regulator in a two-sided market constrained to marginal cost pricing in the content market chooses below-cost pricing in the subscription market.[28]

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[24] The second-order conditions, $-\frac{f(ft-a^2-2ab)}{(ft-ab)^2} < 0$, $-\frac{f(ft-b^2-2ab)}{(ft-ab)^2} < 0$ and $\frac{ft-(a+b)^2}{(ft-ab)^2} > 0$, are satisfied if $ft > (a+b)^2$, which we assume to be the case. Further, we impose $ft - f(v-c) - (a+b)^2 > 0$ and $ft - (a+b)(v-c) - (a+b)^2 > 0$ to ensure that the market is not covered at the optimum.

[25] These inequalities are implied by $v > c$.

[26] In our case, with $a > b$, clearly $s^* < 0 < s^M$. But even in industries where $a < b$ and the platform monopolist subsidizes the other side of the market, we have $s^* < s^M < 0$, that is, the monopolist subsidizes the other side of the market less than would the regulator because the monopolist does not fully internalize the network externality from the availability of more complementary goods on the other side of the market. In general, the unregulated monopolist will impose a higher fee on the other side of the market than the regulated monopolists, $s^* < s^M$, when $ft > a(a+b)^2/(a+3b)$, that is, when there is a sufficiently high differentiation among consumers and content firms.

[27] Choosing s to maximize $TS(c,s)$ gives $s^{**} = -\frac{b(a^2+ft)(v-c)}{t(ft-2ab-b^2)} < 0$ since $ft > (a+b)^2$. The maximized surplus is $TS(c,s^{**}) = \frac{(ft+a^2)(c-v)^2}{2t(ft-2ab-b^2)}$. The sufficient condition for a maximum is $-\frac{t(ft-2ab-b^2)}{(ft-ab)^2} < 0$.

[28] Choosing p to maximize $TS(p,0)$ gives $p^{**} = \frac{(ft-ab)c - a^2v - abv}{ft-2ab-a^2} < c$ since $ft > (a+b)^2$. The maximized surplus is $TS(p^{**},0) = \frac{ft(c-v)^2}{2(ft-a(a+ab))}$. The sufficient condition for a maximum is $-\frac{f(ft-2ab-a^2)}{(ft-ab)^2} < 0$. Comparing $TS(c,s^{**})$ with $TS(p^{**},0)$, we have that $TS(c,s^{**}) - TS(p^{**},0) = -\frac{(a^4+2a^3b-b^2ft)(v-c)^2}{2t(a^2+2ab-ft)(2ab+b^2-ft)} > 0$ if $ft > \frac{a^3}{b^2}(a+2b)$. The

Due to the network effects arising from the complementarity of the content- and Internet subscription market, the planner sets a negative fee to content providers $s^* < 0$ and a subscription price below its marginal cost $p^* < c$ to internalize the externality of content on subscribers and the externality of subscribers on content. The fact that the planner subsidizes content providers suggests that net neutrality (where s is set to zero) may also result in a higher surplus than the private optimum. The fact that s^* is negative is not a proof of net neutrality and the surplus will be higher than at the private optimum because s^* resulted from the *unconstrained* maximization of total surplus for a planner. To see whether net neutrality is better in terms of total surplus than the private optimum, we need to take into consideration that the monopolist is maximizing profits by choosing price p^M, while s^* was calculated based on the planner choosing p^*. Thus, we need to define total surplus under the maintained condition that notwithstanding the level of s, the monopolist chooses price p to maximize its profits. The planner then optimizes this constrained total surplus function and considers whether setting $s = 0$ (that is, imposing net neutrality) is an improvement over the fully private solution. This is done in the next section.

2.7 Welfare Implications of Imposing Net Neutrality

In this subsection, we examine the welfare implications of imposing net neutrality in two ways. First, starting with a regime of net neutrality, we examine the incentive of the platform to set a small positive fee to content providers and the effects of such an action on total industry surplus. To assess these, we examine the incremental change in platform profits and total industry surplus as the fee charged to content providers increases from zero to a small positive value. Naturally, this is done under the maintained assumption that the monopoly platform chooses subscription price $p(s)$ to maximize its profits. Second, we examine the changes in welfare that occur when moving from a privately optimal p, given $s = 0$, to the full private optimum (p^M and s^M).

Thus, we first define total surplus under the restriction that, given s, the monopolist will set his optimal price for subscription $p(s)$, as defined in equation (6a), that is, we define the constrained total surplus function $TS(p(s), s)$. Then, we evaluate the derivatives of the monopolist's profits and total surplus $TS(p(s), s)$ with respect to the fee s at 0.

The monopolist's incentive to increase the fee to content providers from zero

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percentage gains in total surplus in our model when going from marginal cost pricing on one side of the market and optimality on the other to full optimality are $\frac{TS(p^*,s^*) - TS(c,s^{**})}{TS(p^*,s^*)} = \frac{a^2(a+b)^2}{ft(ft-2ab-b^2)} > 0$ and $\frac{TS(p^*,s^*) - TS(p^{**},0)}{TS(p^*,s^*)} = \frac{b^2}{ft-2ab-a^2} > 0.$ The percentage gain in total surplus of optimality over net neutrality is $\frac{TS(p^*,s^*) - TS(p^{NN},0)}{TS(p^*,s^*)} = \frac{a^4 - 2ab^3 + ft(3b^2 + ft) + a^2(b^2 + 2ft)}{4(ft-ab)^2}$.

to a small positive value is

$$\frac{d\Pi\Big|_{\frac{\partial \Pi}{\partial p}=0}}{ds}\Big|_{s=0} = \frac{d\Pi(p(s),s)}{ds}\Big|_{s=0} = \frac{(a-b)(v-c)}{2(ft-ab)}, \tag{23}$$

which is positive when $a > b$. A planner's incentives to increase the fee to the content providers from zero to a small positive value taking into account that the monopolist chooses subscription price $p(s)$ is

$$\frac{dTS\Big|_{\frac{\partial \Pi}{\partial p}=0}}{ds}\Big|_{s=0} = \frac{dTS(p(s),s)}{ds}\Big|_{s=0} = \frac{(v-c)(a(a^2-ab+2b^2)+(a-3b)\,ft)}{4(ft-ab)^2}, \tag{24}$$

which is negative provided that $a < 3b$ and ft is sufficiently large, *i.e.*, if consumers and content providers are sufficiently differentiated. We also require concavity of $TS(p(s),s)$, for which it is sufficient that $a < 2b$.[29] Thus, for $b < a < 2b$ and ft sufficiently large, starting from a zero fee under net neutrality, the incentives of the platform and society go in opposite directions: the monopolist's incentive is for the platform to charge a positive fee to content providers, while the social incentive is for the platform to subsidize content providers. It follows that net neutrality ($s = 0$) is better for society than the profit maximizing solution of the monopoly platform, which implies a positive fee to content providers ($s^M > 0$).

<u>Proposition 3a</u>: Starting from the net neutrality regime of a zero fee to content providers, a platform monopolist optimally choosing his subscription price would like to marginally <u>increase</u> the fee to content providers above zero.

<u>Proposition 3b</u>: Starting from the net neutrality regime of a zero fee to content providers and facing a platform monopolist that chooses the subscription price, a total surplus maximizing planner/regulator will choose to marginally <u>decrease</u> the fee to content providers below zero.

We have shown that a regulator/planner setting a fee s to content providers (expecting the platform monopolist to set his profit-maximizing subscription price $p(s)$) will choose a negative fee s, *i.e.*, will subsidize the content providers. We now calculate this fee, s^{***} and the subscription price $p^{***} = p(s^{***})$ chosen by the monopolist, given this fee. Maximizing the constrained total surplus function $TS(p(s),s)$ with respect to s, we find

$$s^{***} = -\frac{f(a(a^2-ab+2b^2)+(a-3b)ft)(c-v)}{(a^2-6ab-3b^2)ft+4f^2t^2-a(a-2b)(a+b)^2} \tag{25}$$

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[29] Note that $\frac{d^2TS(p(s),s)}{ds^2} = \frac{a(a-2b)(a+b)^2-(a^2-6ab-3b^2)ft-4(ft)^2}{4f(ft-ab)^2} < 0$ provided that *a* < *2b* and *ft* sufficiently large.

and the corresponding monopolist's subscription price

$$p^{***} = \frac{a^2(cft + b^2(2c+v)) + a(2bft(2c+v) - 2cb^3) - a^4 v - ft(3b^2 c - 2ft(c+v))}{(a^2 - 6ab - 3b^2)ft + 4f^2t^2 - a(a-2b)(a+b)^2}. \quad (26)$$

The fee s^{***} to content providers is negative provided that $a < 3b$ and ft is sufficiently large, which we have assumed earlier.[30] Given that the s^{***} is negative, the platform profits from consumers cover the subsidy to content providers if:

$$(\mathrm{ft})^2(3a^2 - 10ab - 9b^2 + 4ft) - a(a+b)(a(a+b)(a^2 - 3ab + 4b^2) + (a-3b)(a+4b)ft) > 0 \quad (27)$$

which is true for a sufficiently large *ft.*[31] Thus, the overall profits of platforms are positive even when, following the regulator's orders, the platform provides subsidy $-s^{***}$ to the other side of the market.

<u>Proposition 4</u>: A total surplus maximizing planner/regulator, facing a platform monopolist that chooses the subscription price, will choose a below-cost fee to content providers, i.e., will subsidize content providers. Even paying the below-cost fee, the platform makes positive profits.

We can also explicitly compare prices, equilibrium participation levels and surplus distribution across a setting where the platform is free to set both s and p, and a setting of net neutrality regulation where s is constrained to equal zero. Starting with net neutrality, consider the impact of removing net neutrality regulation *i.e.*, compare the results from above with the results from the privately optimal solution. The difference in equilibrium price to consumers and fee to content providers as we go away from net neutrality is

$$\Delta p = p^M - p^{NN} = -\frac{(a-b)(a+b)(v-c)}{2(4ft - (a+b)^2)} < 0, \quad (28)$$

$$\Delta s = s^M - s^{NN} = s^M = \frac{(a-b)f(v-c)}{4ft - (a+b)^2} > 0, \quad (29)$$

while the difference in equilibrium participation levels is

$$\Delta n_c = n_c^M - n_c^{NN} = f(v-c)\left(\frac{2}{4ft - (a+b)^2} - \frac{1}{2(ft - ab)}\right) > 0, \quad (30)$$

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[30] For $s^{***} < 0$, it is sufficient to have $a(a(a-b) + 2b^2) + ft(a-3b) < 0$ which is implied by $a < 3b$ and ft sufficiently large.

[31] The condition can be reformulated as

$$4(\mathrm{ft})^3 + (3a^2 - 10ab - 9b^2)(\mathrm{ft})^2 - a(a+b)(a-3b)(a+4b)ft - a(a+b)a(a+b)(a^2 - 3ab + 4b^2) > 0$$

or $A(\mathrm{ft})^3 + B(\mathrm{ft})^2 - C(ft) - D > 0$ with $A = 4 > 0$. Hence, the expression is positive for *ft* sufficiently large.

$$\Delta n_{cp} = n_{cp}^{M} - n_{cp}^{NN} = (v-c)(\frac{a+b}{4ft-(a+b)^2} - \frac{a}{2(ft-ab)}) < 0.^{32} \quad (31)$$

The equilibrium profits of the platform are, of course, higher when it is unconstrained:

$$\Delta\Pi = \Pi^{M} - \Pi^{NN} = f(v-c)^2(\frac{1}{4ft-(a+b)^2} - \frac{1}{4(ft-ab)}) > 0. \quad (32)$$

Total consumer surplus and content provider profits under private optimum are

$$CS_c^M = \frac{2f^2t(v-c)^2}{(4ft-(a+b)^2)^2} \text{ and } \Pi_{cp}^M = \frac{(a+b)^2 f(v-c)^2}{2(4ft-(a+b)^2)^2} \quad (33, 34)$$

and under net neutrality regulation

$$CS_c^{NN} = \frac{f^2t(v-c)^2}{8(ab-ft)^2} \text{ and } \Pi_{cp}^{NN} = \frac{a^2 f(v-c)^2}{8(ab-ft)^2}. \quad (35, 36)$$

The change in consumer surplus when net neutrality regulation is removed is then[33]

$$\Delta CS_c = CS_c^M - CS_c^{NN} = \frac{1}{8} f^2t(v-c)^2(\frac{16}{(4ft-(a+b)^2)^2} - \frac{1}{(ft-ab)^2}) > 0 \quad (37)$$

and the change in content provider profits

$$\Delta\Pi_{cp} = \Pi_{cp}^M - \Pi_{cp}^{NN} = \frac{1}{8} f(v-c)^2(\frac{4(a+b)^2}{(4ft-(a+b)^2)^2} - \frac{a^2}{(ft-ab)^2}) < 0.^{34} \quad (38)$$

We now calculate the change in total surplus that occurs when net neutrality regulation is removed. Total surplus under the private optimum is

$$TS^M = \frac{f(12ft-(a+b)^2)(v-c)^2}{2(4ft-(a+b)^2)^2} \quad (39)$$

and under net neutrality regulation

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[32] This is implied by $2ft - a(a+b) > 0$ which is implied by $ft > (a+b)^2$ that was assumed for the second-order conditions of the unconstrained total surplus optimization.

[33] Note that $\frac{16}{(4ft-(a+b)^2)^2} - \frac{1}{(ft-ab)^2} = \frac{(a-b)^2(4(ft-ab)+(4ft-(a+b)^2))}{(4ft-(a+b)^2)^2(ft-ab)^2} > 0$ since $4ft-(a+b)^2 > 0$.

[34] This is implied by $2ft - a(a+b) > 0$, which is implied by $ft > (a+b)^2$ that was assumed for the second-order conditions of the unconstrained total surplus optimization.

$$TS^{NN} = \frac{f(v-c)^2(a^2-2ab+3ft)}{8(ft-ab)^2}. \quad (40)$$

The change in total surplus is then

$$\Delta TS = TS^M - TS^{NN} = \frac{f(v-c)^2}{8}\left(\frac{4(12ft-(a+b)^2)}{(4ft-(a+b)^2)^2} - \frac{(a^2-2ab+3ft)}{(ft-ab)^2}\right) < 0, \quad (41)$$

which is negative provided that $a < 5b$ and ft is sufficiently large.[35] Thus, removing net neutrality regulation decreases social welfare for this parameter range.

<u>Proposition 5</u>: Comparing net neutrality and the choice of the monopolist platform, we find that the content sector has higher profits at net neutrality, the platform and the consumers are better off in monopoly, and total surplus is higher in net neutrality for sufficiently large differentiation parameters, ft, and when a private monopolist would like to set positive fees to content providers (5b>a>b).

It is interesting that the consumer surplus is higher in monopoly while total surplus is higher at net neutrality. In monopoly, consumers benefit from a lower subscription price since the monopolist has incentives to attract more consumers to generate extra revenue from charging content providers. Although charging content providers leads to lower content provision, the direct effects of a lower subscription price dominates. In contrast, total surplus takes into account the profits of content providers, which are higher under net neutrality. Thus, despite consumers' surplus and platform profits being lower at net neutrality, the total surplus is higher for this parameter range. Note also that for other parameter ranges, such as for smaller *ft*, the total surplus may decrease under net neutrality, as the increase in content provider profits is not sufficiently large to compensate for reductions in consumer surplus and platform profits.

2.8 <u>Summary of Results for Platform Monopolist</u>

We have showed that for reasonable parameter values, the private and social incentives to set a positive fee to content providers diverge. A private monopolist has an incentive to set a positive fee, while a social planner prefers a negative fee. In addition, for a similar range of parameter values, implementing net neutrality regulation is beneficial for total welfare. We have also compared a privately optimal solution where the monopolist is free to set the price to consumers and content providers to the outcome where a zero fee to content providers is imposed. The comparison showed that removing net neutrality regulation will lead to an increase in the fee content providers must pay for access and hence, less content is provided. The price consumers pay for Internet access decreases, so that a larger number of consumers purchase Internet access, but they have access to less content. In the aggregate, consumers and the platform are better off and content providers worse off.

[35] Under assumptions $a > b$ and $ft-(a+b)^2 > 0$, for condition $\Delta TS < 0$ to hold, it is sufficient that $4(a-5b)(ft)^2 + b(a^2+23ab+3b^2)ft - a(a+b)^2(a^2+ab+2b^2) < 0$, which holds for sufficiently large *ft* and $a < 5b$.

The sum of these changes determines the impact on total welfare. It may be positive or negative, but for large *ft* and when a private platform has incentives to charge content providers a positive price (*a*>*b*), total welfare is reduced so that net neutrality regulation is beneficial for society.

3. Duopoly Platforms with Multi-homing Content Providers

We now extend our model to duopoly competition between two platforms with multi-homing content providers. We assume that consumers single-home i.e. each consumer buys Internet access from one platform only. Content and applications providers, however, are assumed to multi-home, *i.e.*, they sell through both platforms, paying the fees charged by platforms. As in monopoly, we assume that platforms only offer linear subscription prices and content provider fees.

Content providers value consumers to the extent that they are willing to pay both platforms to reach all consumers instead of only paying one platform and reaching a subset of consumers (only the consumers subscribing to that platform). In other words, each (atomistic) content provider decides to join each platform independently of joining the other.

3.1 Consumers

There are two platforms (1 and 2) located at $x = 0$ and $x = 1$. We assume that each platform offers the same intrinsic benefit v to consumers. Given an expected number of content providers n^e_{cpk} in each platform k, $k \in \{1, 2\}$, the marginal consumer, indifferent between buying from platform 1 or 2, is located at x_i that obeys

$$v + bn^e_{cp1} - tx_i - p_1 = v + bn^e_{cp2} - t(1 - x_i) - p_2 . \qquad (42)$$

Assuming full market coverage, the sales of the two platforms are

$$n_{c1} = \frac{1}{2} - \frac{b(n^e_{cp2} - n^e_{cp1}) - (p_2 - p_1)}{2t} \text{ and } n_{c2} = 1 - n_{c1} . \qquad (43, 44)$$

3.2 Content Providers

Content providers are defined as in the monopoly model above, that is, they are heterogeneous with respect to the fixed costs for setting up shop. The expected number of consumers that are able to reach each content provider is n^e_{ck}, if the content provider buys access from platform k, $k \in \{1, 2\}$. The total revenue for each content provider is an^e_{ck}.

Platform k collects a fee s_k from each content provider to allow access to its users. Thus, a content provider *j*'s profit from selling through platform k is

$$\pi_{jk} = an^e_{ck} - s_k - fy_j . \qquad (45)$$

Each content provider with $\pi_{jk} \geq 0$ sets up its business, pays platform k for access to its consumers and makes non-negative profits from sales to those consumers. Thus, the marginal content firm which is indifferent between being active and staying out of the market is

$$n_{cpk} = \frac{an_{ck}^e - s_k}{f},\ k \in \{1,2\}\ . \qquad (46, 47)$$

Since consumers single-home, content providers can only reach the consumers of each platform by buying access from that platform.[36]

3.3 Demand

At the equilibrium, each side of the market correctly anticipates its influence on the demand of the other side and therefore, $n_{ck}^e = n_{ck}$ and $n_{cpk}^e = n_{cpk}$, $k \in \{1,2\}$. Thus, the number of consumers and active content providers is given by the solution to the simultaneous equation system of (43, 44) and (46, 47) which is

$$n_{c1} = \frac{1}{2} + \frac{b(s_2 - s_1) + f(p_2 - p_1)}{2(ft - ab)} \text{ and } n_{c2} = \frac{1}{2} - \frac{b(s_2 - s_1) + f(p_2 - p_1)}{2(ft - ab)}, \quad (48, 49)$$

$$n_{cp1} = \frac{a(b(s_1 + s_2) + f(t + p_2 - p_1)) - (a^2 b + 2fts_1)}{2f(ft - ab)} \text{ and} \qquad (50)$$

$$n_{cp2} = \frac{a(b(s_1 + s_2) + f(t + p_1 - p_2)) - (a^2 b + 2fts_2)}{2f(ft - ab)}\ . \qquad (51)$$

3.4 Unrestricted Duopoly Equilibrium

When the duopoly platforms are free to set prices to both consumers and content providers, platform k maximizes

$$\Pi_k(p_1, p_2, s_1, s_2) = (p_k - c)n_{ck} + s_k n_{cpk}, \qquad (52, 53)$$

k = 1, 2, resulting in equilibrium prices

$$p_1^D = p_2^D = t + c - \frac{a^2 + 3ab}{4f} \text{ and } s_1^D = s_2^D = \frac{a-b}{4}.^{37,38} \qquad (54, 55)$$

[36] A "competitive bottleneck" arises as there is no competition for content providers since they make a decision to join one platform independently of the decision to join the other. This phenomenon is common in, for example, competing mobile telecommunications networks (receivers join one network but callers may call all networks) and newspapers (a consumer may subscribe to only one newspaper but advertisers may advertise in all newspapers). See Armstrong (2006).

[37] The second-order conditions are $-\frac{f}{ft - ab} < 0$, $-\frac{(2ft - ab)}{f(ft - ab)} < 0$ and

The firms split the market on the consumer side and the profits are

$$\Pi_1^D = \Pi_2^D = \frac{4ft-(a+b)^2+4(ft-ab)}{16f}. \qquad (56, 57)$$

3.5 Duopoly under Network Neutrality Regulation

Under net neutrality regulation, $s_1 = s_2 = 0$, and the duopolists independently set their prices to consumers to maximize

$$\Pi_1 = (p_1 - c)n_{c1} \text{ and } \Pi_2 = (p_2 - c)n_{c2} \qquad (58)$$

with respect to p_1 and p_2, respectively, resulting in equilibrium prices of

$$p_1^{DNN} = p_2^{DNN} = t + c - \frac{ab}{f}.^{39} \qquad (59)$$

The firms split the market equally on the consumer side and their profits are

$$\Pi_1^{DNN} = \Pi_2^{DNN} = \frac{1}{2}(t - \frac{ab}{f}). \qquad (60)$$

3.6 Welfare Implications of Imposing Network Neutrality in Duopoly

In this section, we proceed as in monopoly by first looking at incentives to set a positive fee to content providers and then making point-to-point comparisons between the duopoly equilibrium outcome under net neutrality regulation ($s_1 = s_2 = 0$) and under no regulation.

We start by comparing the private and the social incentives to set a positive fee to content providers. The individual incentive for a platform (either 1 or 2) to increase its fee to content providers from zero to a small positive value when the opponent is charging a zero fee is

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$\frac{(4ft-(a+b)^2)+4(ft-ab)}{4(ab-ft)^2} > 0$ and are satisfied since we have assumed that $4ft-(a+b)^2 > 0$.

[38] Note that the equilibrium platform prices given s_1 and s_2 are

$$p_1(s_1,s_2) = t + c - \left(\frac{3ab+(2a+b)s_1+(a-b)s_2}{3f}\right), \quad p_2(s_1,s_2) = t + c - \left(\frac{3ab+(2a+b)s_2+(a-b)s_1}{3f}\right).$$

[39] The second-order condition, $-\frac{f}{ft-ab} < 0$, is satisfied since we have assumed throughout that $ft - ab > 0$.

$$\frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_1}\Bigg|_{s_1=s_2=0} = \frac{d\Pi_1(p_1(s_1,s_2),p_2(s_1,s_2))}{ds_1}\Bigg|_{s_1=s_2=0} =$$

$$\frac{d\Pi_2\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_2}\Bigg|_{s_1=s_2=0} = \frac{d\Pi_2(p_1(s_1,s_2),p_2(s_1,s_2))}{ds_2}\Bigg|_{s_1=s_2=0} = \frac{a-b}{3f} > 0 \qquad (61)$$

We define total surplus (TS) as consisting of the consumer surplus

$$CS = \int_0^{n_{c1}} (v + bn_{cp1} - tx - p_1)dx + \int_{n_{c1}}^{1} (v + bn_{cp2} - t(1-x) - p_2)dx, \qquad (62)$$

the sum of platform profits,

$$\Pi_1 = (p_1 - c)n_{c1} + s_1 n_{cp1}, \quad \Pi_2 = (p_2 - c)n_{c2} + s_2 n_{cp2} \qquad (63, 64)$$

and total content provider profits

$$\Pi_{cp} = \int_0^{n_{cp1}} (an_{c1} - s_1 - fy)dy + \int_0^{n_{cp2}} (an_{c2} - s_2 - fy)dy. \qquad (65)$$

Starting with a regime of net neutrality, we examine the incentive of each duopolist to set a small positive fee to content providers and the effects of such an action on the total industry surplus. To assess these effects, we examine the incremental change in a duopolist's profits and in the total industry surplus as the fee charged by this duopolist to content providers increases from zero to a small positive value. Naturally, the total surplus comparison is made under the maintained assumption that duopolists choose their equilibrium subscription prices $p_1(s_1,s_2), p_2(s_1,s_2)$. The derivatives of a constrained total surplus $TS(p_1(s_1,s_2), p_2(s_1,s_2), s_1, s_2)$ with respect to fees s_1 and s_2, respectively, evaluated at $s_1 = s_2 = 0$, are[40]

$$\frac{dTS\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_1}\Bigg|_{s_1=s_2=0} = \frac{dTS(p_1(s_1,s_2),p_2(s_1,s_2))}{ds_1}\Bigg|_{s_1=s_2=0} =$$

[40] The constrained total surplus function $TS(p_1(s_1,s_2), p_2(s_1,s_2), s_1, s_2)$ is concave under assumptions $a^4 + ft(5b^2 - 18ft) - ab^2(15a + 4b) - a(a - 32b)ft < 0$ and $a^4 - 2ab^2(3a + 2b) - (a^2 - 14ab - 5b^2)ft - 9f^2t^2 < 0$. In addition, to ensure that the market is not covered on the content providers' side, we assume that $a + b - 2f > 0$.

$$\frac{dTS\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{\partial s_2}\Bigg|_{s_1=s_2=0} = \frac{dTS(p_1(s_1,s_2), p_2(s_1,s_2))}{ds_2}\Bigg|_{s_1=s_2=0} = -\frac{b}{2f} < 0. \quad (66)$$

Hence, as in monopoly, social and private incentives go in opposite directions in duopoly, if $a > b$. The social incentives are to reduce the fees to content providers below zero, while each duopolist has an incentive to increase its fee to content providers above zero if the rival has a zero fee. Therefore, net neutrality is desirable from a social perspective but undesirable for each duopolist.

Proposition 6a: Starting from the net neutrality regime of a zero fee to content providers by platform duopolists, each duopolist would like to marginally increase its fee to content providers above zero.

Proposition 6b: Starting from the net neutrality regime of a zero fee to content providers and facing platform duopolists that choose subscription prices non-cooperatively, a total surplus maximizing planner will choose to marginally decrease the fee to content providers below zero.

A planner, anticipating the duopolists' subscription equilibrium prices, chooses negative fees to content providers, $s_1 = s_2 = -\frac{b}{2} < 0$, to maximize the constrained total surplus function $TS(p_1(s_1,s_2), p_2(s_1,s_2), s_1, s_2)$. Imposing these fees results in duopoly equilibrium subscription prices $p_1 = p_2 = t + c - \frac{ab}{2f}$. Even paying the subsidy to content providers, the profits of the duopoly platforms are positive at the resulting equilibrium, $\Pi_1 = \Pi_2 = \frac{2ft - (2ab + b^2)}{4f} > 0$.

Proposition 7: A total surplus maximizing planner, facing platform duopolists that choose their subscription prices based on the planner's choice of a fee to content providers, will choose a below-cost fee to content providers. Even paying the below-cost fee, the duopolists make positive profits.

We now consider the incentives of a duopolist to increase its fee to content providers, given a possibly positive fee by its competitor. We evaluate

$$\frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_1}\Bigg|_{s_1=0} = \frac{d\Pi_1(p_1(s_1,s_2), p_2(s_1,s_2))}{ds_1}\Bigg|_{s_1=0} = \frac{(a-b)}{3f} - \frac{(a-b)^2 s_2}{9f(ft-ab)} \quad (67)$$

and therefore,

$$\frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_1}\Bigg|_{s_1=0} - \frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_1}\Bigg|_{s_1=s_2=0} = \frac{d\Pi_1(p_1(s_1,s_2), p_2(s_1,s_2))}{ds_1}\Bigg|_{s_1=0}$$

$$-\frac{d\Pi_1(p_1(s_1,s_2),p_2(s_1,s_2))}{ds_1}\Big|_{s_1=s_2=0} = -\frac{(a-b)^2 s_2}{9f(ft-ab)} < 0. \tag{68}$$

Thus, for $a > b$, platform 1 has a lower incentive to set a positive fee to content providers if platform 2 quotes a positive fee to content providers. Imposing net neutrality on platform 1's competitor will strengthen platform 1's incentives to increase the fee to content providers. Thus, the incentive of a duopolist to depart from net neutrality is higher when the opponent observes net neutrality and not when the opponent charges a positive fee to content providers. Conversely, an action by duopolists to simultaneously depart from net neutrality is not supported by individual non-cooperative incentives and therefore, if it occurs, it arouses the suspicion of collusion on the content side of the market. We discuss collusion on one side of the market with competition on the other side of the market in the next section.

Proposition 8: The incentive of a duopolist to increase its fee to content providers above zero decreases as the rival duopolist charges a higher fee.

Now, we make a point-to-point comparison between unconstrained duopoly and the market equilibrium under net neutrality. As in the monopoly model, we compare changes in price to consumers and fees to content providers when moving from a regime with net neutrality to a regime of no regulation. Since the market is covered in both regimes, consumer participation does not change. The differences in equilibrium prices to consumers and fees to content providers are

$$\Delta p_1 = p_1^D - p_1^{DNN} = \Delta p_2 = p_2^D - p_2^{DNN} = -\frac{a(a-b)}{4f} < 0\,, \tag{69}$$

$$\Delta s_1 = s_1^D - s_1^{DNN} = \Delta s_2 = s_2^D - s_2^{DNN} = s_1^D = s_2^D = \frac{a-b}{4} > 0\,, \tag{70}$$

and the difference in content provider participation is

$$\Delta n_{cp1} = n_{cp1}^D - n_{cp1}^{DNN} = \Delta n_{cp2} = n_{cp2}^D - n_{cp2}^{DNN} = -\frac{(a-b)}{4f} < 0\,. \tag{71}$$

The differences in consumer surplus, platform profits and content provider profits are

$$\Delta CS = CS^D - CS^{DNN} = \frac{(a-b)^2}{16f} > 0, \tag{72}$$

$$\Delta\Pi_1 = \Pi_1^D - \Pi_1^{DNN} = \Delta\Pi_2 = \Pi_2^D - \Pi_2^{DNN} = -\frac{(a-b)^2}{16f} < 0, \tag{73}$$

and

$$\Delta\Pi_{cp} = \Pi_{cp}^D - \Pi_{cp}^{DNN} = -\frac{(a-b)(3a+b)}{16f} < 0\,. \tag{74}$$

Total welfare is reduced when the net neutrality regulation is removed since

$$\Delta TS = TS^D - TS^{DNN} = -\frac{(a-b)(3a+b)}{16f} < 0. \tag{75}$$

Thus, under no regulation, competition for consumers is more intense since profits from content providers can be competed away. As a result, consumers enjoy lower prices and are better off under no regulation than under net neutrality. Net neutrality regulation relaxes price competition, leading to higher profits for platforms. Platforms are better off under net neutrality, which is the opposite to the case in the monopoly model.

Proposition 9: Comparing unconstrained duopoly with duopoly under net neutrality, we find that the total surplus is higher in net neutrality and the content sector and the platforms have higher profits. Consumers are worse off under net neutrality.

An important note is that we assume full market coverage on the consumer side, which implies that price reductions to consumers will only lead to surplus transfers between consumers and platforms. In contrast, on the content provider side, fee increases lead to reductions in the surplus. In the appendix, we provide a detailed discussion of the implications for our results when the market is not fully covered so that there are demand expansion effects also on the consumer side of the market. Our results are similar when accounting for this effect.

3.7 Collusion on Fees to Content Providers

As we have shown, duopolist platforms like the net neutrality regime because it allows them to charge higher subscription prices. However, the individual incentive of each firm is to increase its fee to content providers and depart from net neutrality, provided that the opponent remains at net neutrality. Therefore, in a two-strategy game where each duopolist can set $s_i^{DNN} = 0$ or the non-cooperative equilibrium fee s_i^D, both firms choose s_i^D leading to a prisoners' dilemma equilibrium with lower profits for both platforms than when both play $s_i^{DNN} = 0$. We show below that collusion between platforms will also result in zero fees to content providers if the platforms are constrained to choose non-negative fees.

Suppose that the duopolists first collude on fees to content providers, *i.e.*, set cooperatively s_1 and s_2 to maximize the joint profits $\Pi_1 + \Pi_2$, and then set subscription fees non-cooperatively.[41] Given subscription fees s_1 and s_2, the non-cooperative equilibrium subscription prices are

$$p_1(s_1, s_2) = \frac{b(s_2 - s_1) - a(3b + 2s_1 + s_2)}{3f} + t + c \ , \tag{76}$$

$$p_2(s_1, s_2) = \frac{b(s_1 - s_2) - a(3b + 2s_2 + s_1)}{3f} + t + c \ . \tag{77}$$

Substituting these in joint profits $\Pi_1 + \Pi_2$ and maximizing with respect to s_1 and s_2, we find that the joint profit maximizing fee for the platforms is zero: $s^{DCO} = s_1^{DCO} = s_2^{DCO} = 0$. Therefore, the firms cannot improve over net neutrality if they collude.

[41] Consumers and content providers form expectations and make their decisions subsequently.

Proposition 10: Duopolists colluding in setting fees to content providers while competing non-cooperatively in subscription prices will choose zero fees if they are constrained not to choose non-negative fees. Thus, the duopolists cannot improve over net neutrality by cooperating in linear fees to content providers.

3.7 Summary of Results for Platform Duopoly

Extending the monopoly model to a duopoly setup, we showed that most of our results are robust to the introduction of competition between platforms.[42] In platform duopoly, we find that for a wide range of parameter values, the private and social incentives to set a positive fee to content providers diverge. A social planner would prefer a negative fee, while competing duopolists would like to choose a positive fee. Hence, net neutrality regulation is beneficial for social welfare even when some competition is present in the platform market. Comparisons between outcomes under the private equilibrium with two-sided pricing and the private equilibrium under net neutrality regulation indicated that a removal of net neutrality regulation would lead to a lower subscription price for consumers, but less content available due to an increase in fees to content providers. Content providers are worse off in the aggregate, while consumers are better off. Social welfare is reduced, thereby supporting the result that net neutrality regulation is good for total welfare.

4. Concluding Remarks

We developed a model of a two-sided market to assess the potential benefits of the Internet departing from "net neutrality" whereby broadband Internet access providers (telephone and cable TV companies) do not charge a positive fee to content and application providers. We explicitly allowed monopoly and duopoly access providers to charge a positive fee to content and applications providers. This was contrasted against a setup where a regulator chooses the fee to content providers to maximize the total surplus, taking into account the pricing of a monopolist or duopolists in the consumer subscription side of the market. We showed that under these conditions and under reasonable parameter ranges, the regulator will choose a negative fee to content providers while a monopolist or duopolists will choose positive fees. We also showed that for reasonable parameter values, society is better off in terms of total surplus at net neutrality rather than either the monopolist's or duopolists' choices of positive fees to content providers. However, there are also parameter ranges for which the opposite result is obtained.

As noted in the introduction, the economics literature on net neutrality regulation is still in its early stages. Further rigorous economic analysis is needed on issues such as the impact of net neutrality regulation on innovation among content providers, non-linear platform pricing and congestion and broadband penetration. In particular, the issue of price discrimination and two-part tariffs to consumers and content providers is important. Our results rely quite extensively on the platform not

[42] This echoes earlier theoretical evidence suggesting that introducing competition in a two-sided market does not necessarily lead to a pricing structure that is closer to the socially optimal one. See, for example, Wright (2004), Armstrong (2006) or Hagiu (2007).

being able to appropriate the entire surplus from consumers and content providers. Hence, our results might not be robust to an extensive use of price discrimination and two-part tariffs by the platform. We believe, however, that our results still hold if *some* surplus is left to consumers and content providers. Nevertheless, our focus has been on the two-sided nature of the market and we believe it to be important for future studies to account for this. A one-sided analysis of two-sided markets may easily lead to incorrect conclusions.[43]

[43] See e.g. Wright (2004).

5. Appendix

A. Duopoly Model with Demand Expansion Effects on the Consumer Side

Here, we consider the model of duopoly under the assumption that the market on the consumer side is not covered, *i.e.*, we account for demand expansion effects on the consumer side as is already done on the content provider side. We show that our main conclusions do not change under this scenario.

In contrast to the duopoly model presented above, where the platforms were located at the end points of the unit interval over which consumers are uniformly distributed, we here locate the platforms at a distance $d < \frac{1}{2}$ from the endpoints. We assume that d and t are sufficiently large so that the market is never covered and the platforms compete for consumers located between them. Hence, there will be three marginal consumers denoted x_1, x_2 and x_3. The consumer located at x_1 is indifferent between buying from platform 1 and staying out of the market. The consumer located at x_2 is indifferent between the two platforms and the consumer located at x_3 is indifferent between staying out of the market and buying from platform 2. Given our utility specification, the locations of these indifferent consumers are given by

$$x_1 = d - \frac{v + bn_{cp1}^e - p_1}{t}$$

$$x_2 = \frac{1}{2} - \frac{b(n_{cp2}^e - n_{cp1}^e) - (p_2 - p_1)}{2t}$$

$$x_3 = (1-d) + \frac{v + bn_{cp2}^e - p_2}{t}$$

and demand on the consumer side is $n_{c1} = x_2 - x_1$ and $n_{c2} = x_3 - x_2$. The content provider side remains the same as in section 3.

We can obtain expressions for the number of active consumers and content providers as functions of all four prices. These are

$$n_{c1}(p_1, p_2, s_1, s_2) = \frac{2ab(2bs_1 + f(2p_1 - t + 2dt - 2v)) + ft(b(-3s_1 + s_2) + f(-3p_1 + p_2 + t - 2dt + 2v))}{4a^2b^2 - 6abft + 2f^2t^2}$$

$$n_{cp1}(p_1, p_2, s_1, s_2) = \frac{-2fs_1t^2 + 2a^2b(2p_1 - t + 2dt - 2v) + at(b(3s_1 + s_2) + f(-3p_1 + p_2 + t - 2dt + 2v))}{4a^2b^2 - 6abft + 2f^2t^2}$$

$$n_{c2}(p_1, p_2, s_1, s_2) = \frac{2ab(2bs_2 + f(2p_2 - t + 2dt - 2v)) + ft(b(s_1 - 3s_2) + f(p_1 - 3p_2 + t - 2dt + 2v))}{4a^2b^2 - 6abft + 2f^2t^2}$$

$$n_{cp2}(p_1, p_2, s_1, s_2) = \frac{-2fs_2t^2 + 2a^2b(2p_2 - t + 2dt - 2v) + at(b(s_1 + 3s_2) + f(p_1 - 3p_2 + t - 2dt + 2v))}{4a^2b^2 - 6abft + 2f^2t^2}$$

The consumer surplus is

$$CS = \int_{x_1}^{d} (v + bn_{cp1} - t(d-x) - p_1)dx + \int_{d}^{x_2} (v + bn_{cp1} - t(x-d) - p_1)dx$$
$$+ \int_{x_2}^{(1-d)} (v + bn_{cp2} - t((1-d)-x) - p_2)dx + \int_{(1-d)}^{x_3} (v + bn_{cp2} - t(x-(1-d)) - p_2)dx$$

and the content provider profits are

$$\Pi_{cp} = \int_{0}^{n_{cp1}} (an_{c1} - s_1 - fy)dy + \int_{0}^{n_{cp2}} (an_{c2} - s_2 - fy)dy.$$

Total surplus is defined as the sum of consumer surplus, platform profits and content provider profits.

We first solve for equilibrium prices and fees in the unrestricted duopoly equilibrium. Platform *k* choose prices and fees to maximize

$$\Pi_k(p_1, p_2, s_1, s_2) = (p_k - c)n_{ck}(p_1, p_2, s_1, s_2) + s_k n_{cpk}(p_1, p_2, s_1, s_2)$$

resulting in symmetric equilibrium prices of

$$p_1^D = p_2^D = \frac{ab(8b^2c + ft(-22c - 9t + 18dt - 18v)) + 4a^3b(t - 2dt + 2v) + a^2(3ft(-t + 2dt - 2v) + 4b^2(2c + t - 2dt + 2v)) + 2ft(-3b^2c + 2ft(3c + t - 2dt + 2v))}{8ab(a+b)^2 - 2(3a^2 + 20ab + 3b^2)ft + 20f^2t^2}$$

$$s_1^D = s_2^D = \frac{(a-b)f(4ab - 3ft)(2c + (2d-1)t - 2v)}{8ab(a+b)^2 - 2(3a^2 + 20ab + 3b^2)ft + 20f^2t^2}.$$ [44]

Under net neutrality regulation ($s_1 = s_2 = 0$), equilibrium subscription prices are obtained by each platform setting the price to maximize

$$\Pi_k(p_1, p_2, 0, 0) = (p_k - c)n_{ck}(p_1, p_2, 0, 0)$$

resulting in symmetric subscription prices of

$$p_1^{DNN} = p_2^{DNN} = \frac{ft(-3c - t + 2dt - 2v) + 2ab(2c + t - 2dt + 2v)}{8ab - 5ft}.$$ [45]

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[44] The second-order conditions are $f\left(\frac{1}{ab - ft} + \frac{2}{2ab - ft}\right) < 0$, $\frac{t(3ab - 2ft)}{(ab - ft)(2ab - ft)} < 0$, and $\frac{(3ft - 4ab)(4ab(a+b)^2 - 3(a^2 + 6ab + b^2)ft + 8f^2t^2)}{4(ab - ft)^2(ft - 2ab)^2} > 0$. To satisfy the second-order conditions, we need to impose $ft - 2ab > 0$ and $4ab(a+b)^2 - 3(a^2 + 6ab + b^2)ft + 8f^2t^2 > 0$, that is, that the heterogeneity parameters are sufficiently large.

We now compare the unconstrained duopoly and the market equilibrium under net neutrality. Through rather tedious calculations, it can be shown that for a sufficiently large transportation cost parameter, the differences in equilibrium prices to consumers and fees to content providers are

$$\Delta p_1 = p_1^D - p_1^{DNN} = \Delta p_2 = p_2^D - p_2^{DNN} < 0,$$
$$\Delta s_1 = s_1^D - s_1^{DNN} = \Delta s_2 = s_2^D - s_2^{DNN} > 0$$

and the differences in consumer and content provider participation are

$$\Delta n_{c1} = n_{c1}^D - n_{c1}^{DNN} = \Delta n_{c2} = n_{c2}^D - n_{c2}^{DNN} > 0,$$
$$\Delta n_{cp1} = n_{cp1}^D - n_{cp1}^{DNN} = \Delta n_{cp2} = n_{cp2}^D - n_{cp2}^{DNN} < 0.$$

The differences in consumer surplus, platform profits and content provider profits are

$$\Delta CS = CS^D - CS^{DNN} > 0,$$
$$\Delta \Pi_1 = \Pi_1^D - \Pi_1^{DNN} = \Delta \Pi_2 = \Pi_2^D - \Pi_2^{DNN} > 0,$$
$$\Delta \Pi_{cp} = \Pi_{cp}^D - \Pi_{cp}^{DNN} < 0.$$
$$\Delta TS = TS^D - TS^{DNN} < 0.$$ [46]

Under no regulation, the competition for consumers is more intense since profits from content providers can be competed away. As a result, consumers enjoy lower prices and are better off under no regulation than under net neutrality. Platforms are also better off under no regulation. This is the opposite result to that of the case when the market was covered due to profits from more consumers entering the market. Content providers are worse off and total welfare is reduced.

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[45] The second-order conditions $f\left(\frac{1}{ab - ft} + \frac{2}{2ab - ft}\right) < 0$ are satisfied for $ft - 2ab > 0$.

[46] Total welfare is reduced when net neutrality regulation is removed if $3a - 23b < 0$ and differentiation parameters f and t are sufficiently large so that

$$8a^2b(3a^4 + 18a^3b + 18a^2b^2 + 54ab^3 + 11b^4)ft +$$
$$(39a^3 - 31a^2b + 491ab^2 + 21b^3)f^3t^3 + 5(3a - 23b)f^4t^4 < 16a^3b^2(a+b)^2(a^2 + ab + 2b^2) +$$
$$a(9a^4 + 133a^3b + 48a^2b^2 + 730ab^3 + 76b^4)f^2t^2.$$

B. Marginal Costs on the Content Provider Side

In this part of the appendix, we discuss the effects on our model of incorporating marginal costs on the content provider side of the market. Since our model is set up such that we only consider fees to content providers in excess of the costs related to receiving and sending traffic, it is difficult to imagine positive marginal costs of serving content providers in our setup. However, suppose there to be a marginal cost, k, related to serving content providers. Then,

- Proposition 1 no longer holds. The reason is that the costs for serving content providers imply that there is an additional incentive to raise prices to content providers.

- Propositions 2a-2c need an additional constraint that k is sufficiently small.

- Proposition 3a holds for $f(a-b)(v-c)+(2ft-a^2-ab)k>0$.

- Proposition 3b needs an additional constraint that k is sufficiently small.

- Proposition 4 holds for small k.

- Proposition 5 holds in that platform profits are higher in monopoly. Content sector profits and consumer surplus may be higher or lower under net neutrality and the total surplus may also be higher or lower depending on the value of k.

- Proposition 6a holds.

- Proposition 6b holds for $b-2k>0$ (if k is sufficiently small).

- Proposition 7 holds for $b-2k>0$ (if k is sufficiently small).

- Proposition 8 holds.

- Proposition 9 holds for $6k<a+3b$ (if k is sufficiently small).

- Proposition 10 will not hold. Instead of colluding on setting zero fees to content providers, they will optimally set positive fees to content providers equaling $(1/2)k$ due to the positive marginal costs of serving content providers.

To summarize, for most of our results to hold, we need the potential marginal cost on the consumer side of the market to be sufficiently small. Note also that in our original setup, net neutrality regulation might possibly be interpreted as marginal cost pricing. However, we do not encourage such an interpretation since one central aspect of net neutrality regulation is whether Internet Service Providers should be able to charge content providers or not. Hence, net neutrality regulation should be interpreted as the inability to set positive (or negative) prices to content providers. Marginal cost pricing would involve a potentially positive fee, which is not consistent with our definition of net neutrality.

C. Monopoly Platform Located at Center of Hotelling Line

In this appendix, we consider the monopoly platform as being located not at one end of the unit interval ($x = 0$), but at the centre of the line ($x = \frac{1}{2}$). This implies that the demand functions facing such a monopoly platform become

$$n_c(p,s) = \frac{2(f(v-p)-bs)}{ft-2ab} \text{ and } n_{cp}(p,s) = \frac{2a(v-p)-st}{ft-2ab}$$

and the consumer surplus becomes

$$CS_c(p,s) = \frac{t(bs+f(p-v))^2}{(ft-2ab)^2}.$$

Then, going though the calculations with these new expressions for demand and consumer surplus allows us to check that propositions 1-5 still hold.

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Paying to Remove Advertisements

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Abstract

Casual observation suggests that Internet media firms sometimes allow consumers to pay to remove advertisements from an advertisement-based product. In this paper, I characterize when this business model is optimal for a monopolist and analyze its impact on advertising quantity and surplus distribution. The optimality of the business model depends on the relation among product quality, the annoyance of advertisements and advertisers' profit margins. When consumers can pay to remove advertisements, there is an increase in advertisement quantity and the firm and the advertisers gain at the expense of consumers. Advertising quantity and firm profits may be increasing in the annoyance of advertisements. The impact on total welfare is ambiguous.

Keywords: Advertising, media markets, price discrimination, two-sided markets, vertical differentiation.

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1 Introduction

There are many recent examples of cases where firms allow consumers to pay to remove advertisements from an otherwise ad-based product. For example, *Slashdot.org* allows users to pay $5 for 1000 ad-free pages. *Gamespot.com* offers a monthly subscription for $5.95 that (among some other benefits) removes advertisements[1]. *The Walt Disney Company* offers TV series for purchase through the iTunes store at $1,99 per episode. A free alternative with advertisements is available on their homepage or by watching the show on TV.[2] *We7* offers music downloads with 10 second ads attached for free or at a fee without ads.[3] There are also companies such as *Ultramercial* that allow consumers to "pay" for premium content on websites by watching a series of interactive advertisements.[4]

These examples highlight a strategy where media providers and software companies practice second-degree price discrimination by offering two versions differing in advertising quantity. The strategy is easily followed for online media firms, since advertisements are easily separable from content. Technologies such as streaming video over the Internet also make it easier to charge consumers for an ad-free version of television shows.

The increasing use of this practice raises questions about its impact on advertising quantity and the distribution of surplus among the agents involved. The provision of programming and advertising in the broadcasting industry has been subject to a considerable degree of attention from regulators. For example, advertising quantity is regulated in several European countries. As an increasing amount of advertising expenditures move online, the implications of newly available strategies, such as charging consumers for the removal of advertisements, may become important in policy discussions.[5]

The goal of this paper is two-fold. I first seek to understand when allowing consumers to pay to remove advertisements is optimal for a monopolist media firm. I then seek to analyze how advertising quantity and the distribution of surplus is affected by shifting from a business model of being entirely ad-based to a business model of allowing consumers to pay to remove advertisements. To this end, I construct a model of a two-sided vertically differentiated market. A monopolist media firm may mediate advertisements between advertisers and consumers by attaching them to an already developed product of given quality. Consumers are heterogeneous over their valuation for quality and they perceive advertisements as reducing the quality of the product. Advertisers are monopoly producers of new goods and they are heterogeneous over the purchase probability of their goods. The media firm has three possible business models that can be implemented. The media firm

[1] Slashdot.org (2008) and Gamespot.com (2008)

[2] Bossman (2006) Some cable television companies also offer subscription services for digital video recorders that can be set to automatically remove advertisements from recorded shows.

[3] We7.com (2008)

[4] Ultramercial.com (2008). Ultramercial offers a gallery of over 400 reviews of previous successful campaigns (one example is the online version of The Economist, which can sometimes be fully accessed if the visitor clicks through a sequence of ads or watches a short video).

[5] According to ZenithOpimedia, the total amount spent globally on Internet advertising will exceed advertising expenditures on radio advertising in 2008. Further, the spending rate is predicted to increase six times faster than spending on traditional media between 2006 and 2009 (Ilett, 2007).

can be purely fee-based, purely ad-based or have an ad-based version but allow consumers to pay to remove the ads.

I show the following. A business model for allowing consumers to pay to remove advertisements is more likely to be optimal when the quality of the media firm's product is low, the annoyance of advertisements is high, and advertisers' profit margins are low. Further, the media firm may benefit from an increase in the annoyance of advertisements. Advertising quantity is higher when consumers can pay to remove advertisements as compared to when they cannot and advertising quantity may be increasing in the annoyance of advertisements (this offers a testable implication of the model). Shifting to a business model of allowing consumers to pay to remove advertisements harms consumers but benefits advertisers and the media firm. The impact on total welfare is ambiguous.

Essentially, the idea is that the media firm must balance revenues from consumers and revenues from advertisers. Revenues from advertisers are tied to advertisers' profit margins and the number of consumers viewing ads. Hence, when consumers are highly profitable to advertisers, the media firm is better off not allowing consumers to pay to remove advertisements as this would decrease the number of consumers that view ads. Conversely, if the quality of the media firm's product were relatively high, introducing a free ad-based product would only cannibalize sales from the fee-based alternative. Being purely fee-based is optimal in this case. For cases where advertisers' profit margins and the quality of the media firm's product are low in relation to the annoyance of ads, it may be the case that the cannibalization effect is sufficiently low. Then, having a free ad-based version and allowing consumers to pay to remove advertisements is optimal.

In this case, profits are increasing in the annoyance of ads, since the cannibalization effect from the free version is reduced and higher prices can be charged for the removal of ads. Further, the advertising quantity is higher than under a purely ad-based business model. This is the case since a higher price can be charged for removing advertisements if the ad-based version has a larger number of ads. Advertising quantity is also increasing in the annoyance of ads, since the marginal impact of an increase in advertising quanity on utility is higher when the annoyance of advertisements is higher. Consumer welfare is reduced as compared to only offering an ad-based version, even though consumers have more options. Consumers using the ad-based version view more ads. Consumers paying to remove the ads pay a price that causes them more disutility that what watching ads would have caused them.

The paper is organized as follows. The next section discusses related literature. Section 3 describes the setup of the model. I solve for optimal prices under three different business models (fee-based, ad-based and paying to remove advertisements) and compare under what condition each business model is optimal in section 4. Section 5 compares the change in advertising quantity and the distribution of surplus when the media firm moves from being purely ad-based to allowing consumers to pay to remove advertisements. The final section concludes the paper.

2 Related Literature

This paper is related to the literature on price discrimination in media markets. Previous analyses in the media market literature have focused on welfare issues related to pay-per-view versus free airing of outstanding events (such as boxing matches). Price discrimination is an issue since the media firm can require consumers to pay to watch the event live and then air it for free a day later. This is the setup in Holden (1993) which concludes that consumers are harmed by the possibility of pay-per-view. Hansen and Kyhl (2001) consider a slightly different setup where the pay-per-view version contains advertisements and a free version is not available. They analyze how a ban on pay-per-view affects welfare. They find that consumer welfare is enhanced by a ban, but the overall impact on welfare is ambiguous. A recent addition to the literature is by Anderson and Gans (2007), who examine the impact on broadcaster behavior when consumers adopt advertising avoidance technologies. They show that advertising quantity could increase, as the remaining consumers are less averse to advertising. As a result, overall welfare and program quantity could decrease and programming would be tailored to appeal to a broader range of viewers.[6]

Price discrimination in media markets has also attracted some attention in the marketing literature. Prasad, Mahajan, and Bronnenberg (2003) analyze the incentives to price discriminate when consumers are of two given types and a media firm may offer two versions differing in advertising quantity and price. They show that offering two versions (price discrimination) tends to be optimal in most cases.

For the cases that I have in mind, the media firms typically provide one free ad-based version and one fee-based version. The versions are similar, so that consumers essentially pay to remove the advertisements. The effects on pricing and surplus distribution of offering consumers the opportunity to pay to remove all advertisements have not so far been explored in the literature so far. An analysis of this case is important, since the provision of the option to pay to remove advertisements is likely to affect advertising quantity and the distribution of surplus among agents. Holden (1993) does consider this type of setup, but he only examines the impact on consumer surplus. Further, consumers are homogeneous in terms of the impact of advertising on utility in his model. Consumers with a heterogeneous aversion to advertising appear in Anderson and Gans (2007) and Prasad et al. (2003). However, Anderson and Gans (2007) do not consider the simultaneous determination of the price for a fee-based version and the price for advertising space. They mainly focus on the case where advertising avoidance technologies are acquired from other

[6]Anderson and Gans (2007) employ a two-sided market approach, which is also the case in this paper. Hence, this paper is also related to two-sided media markets, e.g. Anderson and Coate (2005), and to the two-sided market literature in general, e.g. Caillaud and Jullien (2003) and Rochet and Tirole (2003). A crucial difference between second-degree price discrimination in one-sided markets as compared to the current setup using a two-sided market approach is that the price and the quality of the lower quality version depend on the price for advertising space set on the other side of the market. In a one-sided market, prices are set given the quality of the different versions. Here, as prices for the versions change, so does the attractiveness of advertising space to advertisers. This, in turn, affects the optimal price for advertising space and the amount of advertising determining the quality of the lower quality version.

suppliers than the broadcaster.

In spirit, the analysis of Prasad et al. (2003) might be closest to the analysis in this paper. In their paper, advertising has a negative effect on the quality of the media firm's product. However, Prasad et al. (2003) only consider two types of consumers while I model consumer types as continuously distributed on an interval. This allows for a closer connection between the consumer and the advertiser side of the market. Moreover, an ad-free version is not available in Prasad et al. (2003). Both versions contain advertisements. Further, they do not provide a welfare analysis. I also incorporate a parameter in my model measuring the extent to which advertising has an impact on the perceived quality of the product of the media firm (the annoyance of ads). The parameter becomes an important determinant of the optimality of offering consumers both an ad-based and a fee-based version. It determines the extent to which the free ad-based version cannibalizes sales of the fee-based version.

In addition, this paper relates to the literature on damaged goods.[7] Deneckere and McAfee (1996) show that under specific conditions, a costly reduction of quality ("damaging" an already developed product) can lead to a Pareto improvement. Examples of other studies of bundling a bad with a good to reduce quality is Chiang and Spatt (1982), where the bad is time costs and Salop (1977) where the bad is search costs. Here the bad is advertisements. A firm can degrade the quality of a product already developed by attaching advertisements to it. Compared to degrading quality by other means, damaging goods with advertisements is different since it generates a new source of revenues. This gives the firm an additional incentive to "damage" its goods.

3 The Model

Having described the relation to the literature in the previous section, this section describes the setup of the model. It is a model of a two-sided vertically differentiated market.[8] A monopolist media firm has a product of a given quality to which advertisements can be attached. Consumers are heterogeneous over their valuation for quality and they perceive advertisements as reducing the quality of the product. Advertisers are monopoly producers of new goods and they are heterogeneous over the purchase probability of their goods. The relationship among the media firm, consumers and advertisers is outlined in figure 1. I now describe the media firm, the consumers and the advertisers in detail.

[7] For a great treatment of damaged goods and versioning, see Varian (2001).

[8] The model is quite closely related to models that appear in Katsamankas and Bakos (2004) and Gabszewicz and Wauthy (2004). However, I consider negative externalities in one direction and incorporate a form of price discrimination towards one side of the market.

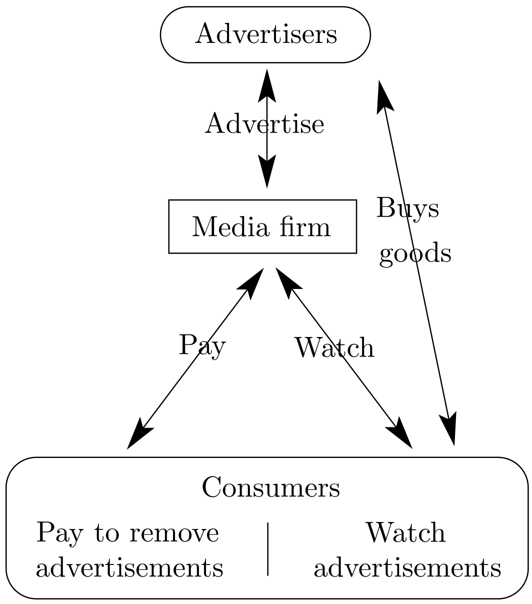

Figure 1: Relationship among advertisers, the media firm and consumers.

3.1 The Media Firm

Consider a monopolist media firm that has developed a good of the intrinsic quality level v.[9] The fixed costs related to the development of this product are sunk and duplication carries small or zero costs. The media firm interacts with consumers and advertisers and can choose between three business models.

1. *Fee-based:* The media firm could sell the product to consumers at the price p_c to consumers and not have any ads.
2. *Ad-based:* The media firm could offer the product to consumers for free and sell ad-space to advertisers at the price p_a.
3. *Paying to remove advertisements:* The media firm could offer both the product without ads at the price p_c and the product with ads for free and sell ad-space at price p_a.

The media firm chooses the business model that offers the highest profits, given optimal prices.[10] The ad-based version is explicitly constrained to carry a zero price. This specification is important and motivated by the examples in the introduction, where firms are observed to specifically offer consumers who are otherwise enjoying a free ad-based version the option to pay to remove all advertisements.[11]

[9] The media firm can be a broadcaster, a magazine, a software firm, a website or any other kind of firm that can embed advertisements in its product.

[10] I assume that the price for removing advertisements is set simultaneously with the price for ad-space

[11] A fourth possible business model would be to consider a fee-based version with ads. I do not consider this alternative since I want to focus on the specific case of either a fee-based version or an ad-based version.

3.2 Consumers

I consider a continuum of consumers of mass N with unit demand. Consumers dislike ads and perceive a good with ads as a good of inferior quality. For the markets I have in mind, it seems reasonable to assume that consumers dislike ads. First, consumers are observed to be willing to pay to remove advertisements so they clearly reveal a preference for consuming the product without ads. Second, there is casual evidence that advertising is not desirable. For example, according to Ehomeupgrade.com (2007), a report issued by DIGDIA (www.digdia.com) showed that 44% of the consumers would prefer to watch a movie on TV without ads and paying \$3.99, while only 17% would pay \$2.99 and watch the content on TV with ads. The other options were buying a DVD (27%), downloading the movie and watching it on the computer for \$3.99 (9%) and watching the movie on the computer with ads for \$2.99 (3%). As expressed by Ehomeupgrade.com (2007): "Over 250% more people would rather pay an extra dollar just to avoid ads with their movie".

Hence, I assume that consumers dislike advertisements.[12] Specifically, consumers perceive a good with advertisements to be of quality $q = v - \gamma a$. Variable a denotes advertisement quantity and γ measures the impact of advertising on quality. This is interpreted as the general annoyance level of advertisements. I want to focus on the case where quality is positive so I set a to be equal to the share of advertisers that choose to advertise and I assume that $\gamma \in [0, v]$.

Consumers are heterogeneous with respect to their marginal valuation of quality denoted by θ. The distribution of θ is uniform on the unit interval. Hence, a consumer indexed by i obtains utility

$$u_i = \begin{cases} \theta_i v - p_c & \text{if using the fee-based version (removing ads)} \\ \theta_i(v - \gamma a) & \text{if using the ad-based version} \\ 0 & \text{otherwise} \end{cases}, \quad (1)$$

where p_c is the price consumers pay to remove advertisements (or simply the price for the product if the free version is not available). Hence, the "cost" for consumers of the media firm's product is either the price p_c or the individual disutility $\theta_i \gamma a$ incurred due to ads being present. The fraction of consumers adopting the fee-based version of the product is given by m, while the fraction adopting the free ad-based version is given by n.

The specific dependence of quality on advertising used here allows consumers to be heterogeneous both in terms of intrinsic product quality *and* the impact of advertising on their utility.[13] This is consistent with the interpretation that advertisements degrade

[12] This is in line with Holden (1993), Hansen and Kyhl (2001), Prasad et al. (2003) and Anderson and Gans (2007).

[13] A heterogeneous impact of advertising on utility is an important difference between my model and the analyses in Holden (1993) and Hansen and Kyhl (2001). Heterogeneous aversion to advertising is part of the analysis in Prasad et al. (2003), but they do not consider to what extent advertisements have an impact on utility. Essentially, the assumption is that $\gamma = 1$. Moreover, they only consider two consumer types (θ_H and θ_L).

the perceived quality of the product. It seems reasonable to assume that consumers who value quality more also dislike advertisements more. First, in many cases, advertising takes up space, which reduces the amount of content. The reduction of content is more important for consumers who value content highly. Second, advertising requires attention from consumers. Consumers who value quality highly might have a higher opportunity cost of time and hence, dislike advertisements more.

3.3 Advertisers

The advertisers, a mass of 1, are monopoly producers of new goods.[14] Advertising fills the role of informing consumers about the prices and characteristics of their goods.[15] Each advertiser has developed a new good characterized by its type σ uniformly distributed on the unit interval. The type of the good indicates its purchase probability after being advertised. Goods of higher type are more likely to be bought after being advertised. I assume the profit margin on the goods sold by the advertisers to be equal to s. An advertiser j is willing to pay a maximum price of $\sigma_j snN$ to place an advertisement in the media firm's product. The advertiser j profits from advertising according to

$$\pi_j = \begin{cases} \sigma_j snN - p_a & \text{if advertising} \\ 0 & \text{otherwise} \end{cases} . \qquad (2)$$

A possible extension of this framework would be to consider the case where the profit margins of the advertisers are dependent on consumers' valuation of quality, θ. Relaxing this assumption would have at least two implications.

First, a formal model of how advertisers price their goods would be needed. Their pricing decision would be dependent on how many consumers use the ad-based version offered by the media firm and hence, on the price for removing advertisements.[16] Second, consumers would be left with some surplus from purchasing advertisers' goods and hence, have to balance the disutility from having advertisements with possible gains from being informed about a useful product generating utility. These are important aspects to account for, but unfortunately they are not a straightforward extension of this model and they are left to future research.

To summarize, I construct a model of a two-sided vertically differentiated market where a media firm may mediate advertisements between advertisers and consumers. Consumers are heterogeneous over their valuation of quality and they perceive advertisements as reducing the quality of the product. Advertisers are monopoly producers of new goods

[14] So $N > 1$ implies that there are relatively more consumers than advertisers.

[15] Note that I refer to the good sold and produced by the media firm as the *product*. The goods advertisers produce and sell are referred to as *goods*. For a discussion of the different roles of advertising see, for example, Bagwell (2005). The advertising market used in this model is partly adopted from Anderson and Coate (2005).

[16] Alternatively, only the profit margin could be dependent on θ and the pricing problem could be bypassed. This is the case in Prasad et al. (2003).

and they are heterogeneous over the purchase probability of their goods. The media firm has three possible business models that can be implemented. The media firm is purely fee-based, purely ad-based or the firm allows consumers to pay to remove advertisements.

4 Solving the Model

Having described the setup of the model, I now solve for optimal prices under the three different business models that the media firm can adopt. I then compare profit levels to check when each business model is optimal. Solving the model shows that a business model of allowing consumers to pay to remove advertisements is more likely to be optimal when the quality of the media firm's product is low, the annoyance of advertisements is high, and advertisers' profit margins are low. Further, the media firm may have an incentive to increase the annoyance of advertisements.

4.1 Fee-based

Consider the business model where the media firm is entirely fee-based and offers no ad-based product. Let the consumer who is indifferent between buying and not buying the fee-based product be of type θ_c. Then, consumers of type $\theta \in [\theta_c, 1]$ buy the product. The location of θ_c is given by

$$\theta_c v - p_c = 0. \tag{3}$$

Demand for the fee-based product is then $Nm(p_c) = N(1-\theta_c) = N(1-\frac{p_c}{v})$ for $p_c \in [0, v]$, $Nm(p_c) = 0$ for $p_c > v$ and $Nm(p_c) = N$ otherwise. The media firm's profit function is

$$\Pi_F(p_c) = p_c N m(p_c) \tag{4}$$

The media firm chooses the price to maximize profits.

Proposition 1. *When the media firm is fee-based, the price for the product is* $\frac{v}{2}$ *and profits are* $\Pi_F = N\frac{v}{4}$.

Proof. The first-order condition is given by $N(1 - \frac{2p_c}{v}) = 0$ which gives $p_c = \frac{v}{2}$. The second-order condition is satisfied since $-N\frac{2}{v} < 0$. Substituting $p_c = \frac{v}{2}$ in $\Pi_F(p_c)$ gives $\Pi_F = N\frac{v}{4}$. □

When the media firm is fee-based, a higher quality product implies higher profits. An increase in the number of consumers has the same effect. Optimal prices and profits do not depend on characteristics on the advertiser side of the market.

Consumers are heterogeneous with respect to quality. Hence, one might ask whether the media firm would find it optimal to price discriminate by offering two versions of the good, v_H and v_L, such that $v_H > v_L$. It can be shown that this kind of price discrimination is not optimal. The reason is that marginal costs are zero and not affected by the quality level. Hence, there is no reduction in marginal costs when quality is reduced. It is then optimal to only offer one version (with the current utility specification).[17]

4.2 Ad-based

I now consider the business model where the firm is entirely ad-based. Consumers cannot pay to remove advertisements. Let the advertiser who is indifferent between advertising and not advertising own the good of type σ_a. Then, advertisers with goods of type $\sigma \in [\sigma_a, 1]$ will advertise. The total advertising quantity is $a = (1 - \sigma_a)$. The location of σ_a will be given by

$$\sigma_a sN - p_a = 0. \tag{5}$$

Notice that all consumers watch the ads ($n = 1$) since the media firm's product is free when the media firm is entirely ad-based and quality is always non-negative ($v - \gamma a \geq 0$). Demand for ad-space can then be expressed as $a(p_a) = (1 - \frac{p_a}{sN})$ for $p_a \in [0, Ns]$, $a(p_a) = 0$ for $p_a > Ns$ and by $a(p_a) = 1$ otherwise. The media firm's profit function is given by

$$\Pi_A(p_a) = p_a a(p_a). \tag{6}$$

The firm chooses the price for ad-space so as to maximize profits.

Proposition 2. *When the media firm is ad-based, the optimal price for ad-space is* $\frac{sN}{2}$ *and the profits are* $\Pi_A = \frac{sN}{4}$. *The advertising quantity is* $\frac{1}{2}$.

Proof. The first-order condition is given by $1 - \frac{2p_a}{sN} = 0$ which gives $p_a = \frac{sN}{2}$. The second-order condition is satisfied since $-\frac{2}{sN} < 0$. Substituting $p_a = \frac{sN}{2}$ in $a(p_a)$ and $\Pi_A(p_a)$ gives $a = \frac{1}{2}$ and $\Pi_A = \frac{Ns}{4}$. □

When the firm is ad-based, all consumers use the product and view the ads. The media firm can charge more for ad-space if advertisers' profit margins (s) are higher or if there are more consumers (N) in the market viewing the advertisements. Notice that the level of annoyance of advertisements (γ) is of no importance for the media firm since profits are not earned from consumers and the annoyance is assumed to be sufficiently low so for no consumers to stop using the media firm's product.

4.3 Paying to Remove Advertisements

In this subsection, I consider paying to remove advertisements. Both the fee-based and the ad-based version are hence available. Consumers not choosing the ad-based version adopt the fee-based version (pay to remove ads). I first characterize demand formation and then solve for optimal prices, profits and advertising quantity. I only consider interior solutions where demand for the fee-based product and demand for ad-space are positive.

[17] See, for example, Bhargava and Choudhary (2001).

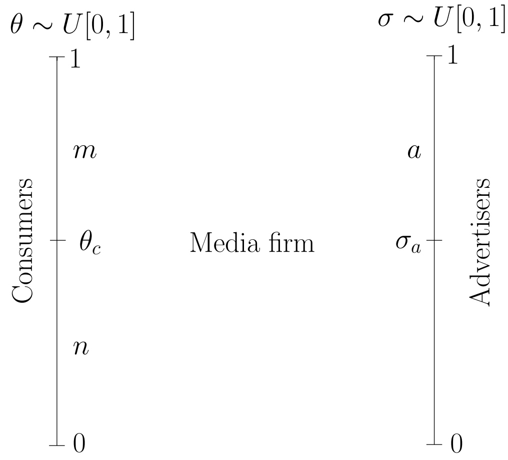

Figure 2: Demand structure facing the media firm when consumers can pay to remove advertisements.

4.3.1 Demand Formation

Let θ_c denote the consumer who is indifferent between paying to remove advertisements and using the ad-based version for free. Given prices, it must then be the case that consumers with $\theta \in [\theta_c, 1]$ pay while consumers with $\theta \in [0, \theta_c]$ use the free version. Using equation (1), the location of the indifferent consumer can be obtained from the indifference equation

$$\theta_c v - p_f = \theta_c v - \theta_c \gamma a \tag{7}$$

for θ_c. This gives $\theta_c = \frac{p_c}{\gamma a}$. Demand for the ad-based version is then given by $Nn(p_c, a) = N(\frac{p_c}{\gamma a})$ for $p_c \in [0, \gamma a]$, by N for $p_c > \gamma a$ and by 0 otherwise. Demand for the fee-based version is $Nm(p_c, a) = N[1 - n(p_c, a)]$. All consumers acquire the media firm's product, but only fraction n views the ads.

Let the advertiser that is indifferent between advertising and not advertising own the good of type σ_a. Advertisers with goods of type $\sigma \in [\sigma_a, 1]$ advertise and the location of σ_a is given by the indifference equation

$$\sigma_a snN - p_a = 0. \tag{8}$$

Demand for ad-space is then $a(p_a, n) = (1 - \frac{p_a}{snN})$ for $p_a \in [0, snN]$, 0 for $p_a > snN$ and 1 otherwise. Demand is illustrated in figure 2.

To account for the fact that demand for ad-space depends on demand for the ad-based version and *vice versa*, I assume that consumers form rational expectations regarding the participation of advertisers and that advertisers form rational expectations regarding the participation of users (see Katz and Shapiro (1985)).[18] Rational expectations on behalf

[18]This problem does not arise in Holden (1993) or Hansen and Kyhl (2001) since the media firm directly sets the advertising quantity resulting in some level of ad-revenue. Consumers observe this level of advertising before their purchase. Advertisers have no choice between advertising or not and hence, it is not specifically modelled how they value consumers. The choice is present in Prasad et al. (2003), but they do

of advertisers and consumers require that the following system of equations be solved in order to obtain demand as functions of price on both sides of the market:

$$n(p_c, a) = n = (\frac{p_c}{\gamma a}) \tag{9}$$

$$a(p_a, n) = a = (1 - \frac{p_a}{snN}) \tag{10}$$

This system has the solutions $n(p_c, p_a) = \frac{p_a}{sN} + \frac{p_c}{\gamma}$ and $a(p_c, p_a) = \frac{sNp_c}{sNp_c + p_a\gamma}$, which give the share of consumers viewing the advertisements and demand for ad-space as functions of the price for removing advertisements and the price for ad-space. Demand for the ad-based version is $Nn(p_c, p_a)$ and demand for the fee-based version is $N[m(p_c, p_a)]$.

4.3.2 Pricing

The media firm sets the price for the fee-based version and price for ad-space to maximize

$$\Pi_{F+A} = N[m(p_c, p_a)]p_c + a(p_c, p_a)p_a \tag{11}$$

subject to the constraints that $0 \leq p_a \leq sNn(p_c, p_a)$ and $0 \leq p_c \leq \gamma a(p_c, p_a)$. I only consider interior solutions where no constraints bind. The solution to this maximization problem yields proposition 3.

Proposition 3. *When the media firm offers both an ad-based and a fee-based version of its product, the optimal advertising quantity is* $\frac{1}{3} + \frac{\gamma}{3s}$*, the price for ad-space is* $p_a = N\frac{1}{9}(s + \frac{2s}{\gamma} - \gamma)$*, the price for the fee-based version is* $p_c = \frac{(s+\gamma)^2}{9s}$ *and the profits are* $\Pi_{F+A} = N\frac{(s+\gamma)^2(2\gamma - s)}{27s\gamma}$*. The profits from consumers are increasing in* γ *and decreasing in* s*. The profits from advertisers are decreasing in* γ *and increasing in* s*.*

Proof. Assume the solution to be interior so that none of the constraints are binding. Taking the first-order conditions and solving the resulting simultaneous equation system yields two solutions for $\{p_c, p_a\}$ given by $\{\frac{(s+\gamma)^2}{9s}, \frac{1}{9}N(s - \gamma + \frac{2s^2}{\gamma})\}$ and $\{0, N\frac{s(s+\gamma)}{\gamma}\}$. The determinants of the principal minors evaluated at each solution point are $\{\frac{2}{3}N(\frac{9}{s+\gamma} - \frac{1}{s} - \frac{7}{\gamma}), \frac{3}{s^2}\}$ and $\{2N(\frac{1}{s+\gamma} - \frac{2}{\gamma}), -\frac{1}{s^2}\}$. They should alternate in sign such that the first is non-positive and the second is non-negative for the solution to be a maximum. Since $-\frac{1}{s^2} < 0$, the optimum cannot be the solution characterized by $\{0, N\frac{s(s+\gamma)}{\gamma}\}$. The second-solution satisfies the second order conditions if $\frac{2}{3}N(\frac{9}{s+\gamma} - \frac{1}{s} - \frac{7}{\gamma}) < 0$. Denote the candidate solution by stars. Use $n(p_c^*, p_a^*)$ and $a(p_c^*, p_a^*)$ to obtain expressions for demand in terms of the exogenous variables. This gives $n^* = \frac{s+\gamma}{3\gamma}$ and $a^* = \frac{s+\gamma}{3s}$. It is now apparent that the solution is an interior optimum only if $\frac{s}{\gamma} \in]\frac{1}{2}, 2[$, since otherwise the prices are not consistent with demand configurations in the range $Nn \in [0, N]$ and $a \in [0, 1]$. Since $\frac{2}{3}N(\frac{9}{s+\gamma} - \frac{1}{\gamma} - \frac{7}{\gamma}) < 0$ for this range, the candidate solution is the optimum.

not face this problem either since there are only two consumer types in their model.

At the boundary where $\frac{s}{\gamma} = 2$, $p_c = 0$ and $p_a = \frac{sN}{2}$, the problem reduces to that where only the ad-based version is offered. At the other boundary $\frac{s}{\gamma} = \frac{1}{2}$, $p_c = \frac{\gamma}{2}$ and $p_a = 0$, all advertisers buy ad-space so that consumers are indifferent between not using the fee-based version and taking the outside option. The maximum profit that can be achieved by the media firm at this boundary occurs when $\gamma = v$. In this case $\Pi_F = \Pi_{A+F}$ in which case I assume that the media firm prefers to be purely fee-based. For any $\gamma < v$, it must be that a business model of being entirely fee-based is optimal at the boundary.

Profits can be split into profits from consumers and profits from advertisers. Profits from consumers are given by $\Pi^C_{A+F} = N\frac{(2\gamma-s)(\gamma+s)^2}{27\gamma s}$ and profits from advertisers are given by $\Pi^A_{A+F} = N\frac{(2s-\gamma)(\gamma+s)^2}{27\gamma s}$. It is then the case that $\frac{\partial \Pi^C_{A+F}}{\partial \gamma} = N\frac{4\gamma^3+3\gamma^2 s+s^3}{27\gamma s^2} > 0$, $\frac{\partial \Pi^C_{A+F}}{\partial s} = -N\frac{2(\gamma^3+s^3)}{27\gamma^2 s} < 0$, $\frac{\partial \Pi^A_{A+F}}{\partial \gamma} = -N\frac{2(\gamma^3+s^3)}{27\gamma^2 s} < 0$ and $\frac{\partial \Pi^A_{A+F}}{\partial s} = N\frac{4s^3+3\gamma s^2+\gamma^3}{27\gamma s^2} > 0$. □

The proposition shows that the price for removing advertisements, the price for ad-space and total profits of the media firm depend on characteristics on both sides of the market. The optimal source of revenues for the media firm depends on the relation between γ and s, since this determines the ability to extract revenue from consumers relative to the ability to extract revenue from advertisers. By setting the price for removing advertisements and the price for ad-space, the media firm can determine what share of consumers views ads and what share pays to remove them. A higher annoyance of ads implies that more can be charged for removing them; hence consumers become a more important source of revenues relative to advertisers. If there is an increase in the profit margins of advertisers, this implies that they are willing to pay more for reaching each consumer. Consumers then become relatively more important as viewers of ads compared to being paying consumers, and hence revenues from advertisers increase in relative importance.

The overall profits are increasing in both γ and s. That overall profits increase in s might be intuitive, since there is “more surplus to be shared”. However, that overall profits increase in γ is perhaps less intuitive. They increase in γ since advertisements are more annoying, this implies that the price for removing advertisements can be increased. At the optimum, the profit gains from consumers outweigh the losses in profits from advertisers (due to a smaller number of consumers viewing advertisements).

The fact that the profit is increasing in γ implies that the media firm would have incentives to increase the general level of annoyance of ads. As will be shown below, a higher γ (when allowing consumers to pay to remove advertisements is optimal) increases the advertiser surplus since the optimal ad-price is decreasing in γ. Hence, advertisers may not object to actions by the media firm that make advertisements more annoying. They may even contribute through the design of their advertisements.

A final point to note is the following. Providing two versions differing in quality (fee-based and ad-based) is essentially second-degree price discrimination. As discussed above, price discrimination by simply providing two versions differing in their inherent quality is not optimal in this model, since there are no savings in terms of marginal costs from providing a lower quality version. However, price discrimination by degrading quality with advertisements may be optimal since the profits from selling advertising space act as a negative marginal cost. More ad-space is sold when the quality is lower. Compared to only providing a fee-based version, the profits from consumers actually decrease when two versions differing in perceived quality are offered. The profit loss is compensated by the gains from selling ad-space, however.[19]

4.4 Comparing Business Models

Through comparisons of profit levels from propositions 1, 2 and 3, the following proposition can be obtained.

Proposition 4. *For $\frac{s}{\gamma} \in [0, \frac{1}{2}]$, only a fee-based version is optimal. For $\frac{s}{\gamma} \in]\frac{1}{2}, 2[$ and $v < v^*$ a fee-based version and an ad-based version should be made available so that consumers can pay to remove advertisements. If $\frac{s}{\gamma} \in]\frac{1}{2}, 2[$ and $v \geq v^*$, only a fee-based version is optimal. For $\frac{s}{\gamma} \in [2, \infty[$ and $v < v^{**}$, the media firm should be purely ad-based. If $\frac{s}{\gamma} \in [2, \infty[$ and $v \geq v^{**}$, then only a fee-based version is optimal.*

Proof. Through the proof for proposition 3, $\Pi_F \geq \Pi_{A+F} > \Pi_A$ if $\frac{s}{\gamma} \leq \frac{1}{2}$ since $\gamma \leq v$. This gives the first part of the proposition. If $\frac{s}{\gamma} \in]\frac{1}{2}, 2[$ then $\Pi_{A+F} > \Pi_A$ by the proof for proposition 3 but it may be that $\Pi_F \geq \Pi_{A+F}$. This is the case for $v \geq v^*$ where v^* is such that $\Pi_F - \Pi_{A+F} = N\frac{v^*}{4} - N\frac{(\gamma+s)^2}{27\gamma s} = 0$. This gives the second part. If $\frac{s}{\gamma} \geq 2$, then $\Pi_A > \Pi_{A+F}$ by the proof for proposition 3 but it may be that $\Pi_F \geq \Pi_A$. This is the case for $v \geq v^{**}$ where $v^{**}$is such that $\Pi_F - \Pi_A = N\frac{v^{**}}{4} - N\frac{s}{4} = 0$. □

The intuition behind proposition 4 is the following. When ad-space is sold, the media firm has two possible sources of revenues. It can either charge consumers for a fee-based version or charge advertisers for access to consumers. Consumers' willingness to pay for a fee-based version is related to the annoyance of advertisements (γ). Advertisers' willingness to pay for ad-space is related to their profit level(s). Hence, the relation between the two variables determines on what source of revenues the media firm should focus. However, it may be the case that simply selling the product to consumers and not involving advertisers is optimal. This is the case if product quality (v) is sufficiently high so that offering a free ad-based version is suboptimal, due to concerns about cannibalization of sales of the fee-based version.

To summarize, solving the model showed that allowing consumers to pay to remove advertisements is optimal if the ratio $\frac{s}{\gamma}$ is in an intermediate range and v is sufficiently low. This implies that a business model for allowing consumers to pay to remove advertisements is more likely to be optimal when the quality of the media firm's product is low, the impact of advertising on quality is high and advertisers' profit margins are low.

[19]There is a slight difference in that the lower quality version has no price in this model and that no consumers drop out of the market when two versions are offered. However, the intuition on why offering two versions may be optimal still holds.

5 Advertising Quantity and Surplus Distribution

Having outlined optimal prices under the different business models and having compared them I now shift to analyze the implications on advertising quantity and the surplus distribution of a shift from being ad-based to allowing consumers to pay to remove advertisements. I first analyze the difference in advertising quantity and then consider the difference in the surplus distribution. I show that advertising quantity is higher when consumers can pay to remove advertisements as compared to when they cannot. This yields a testable implication of my model. Further, advertising quantity may be increasing in the annoyance of advertisements. Shifting to a business model for allowing consumers to pay to remove advertisements harms consumers but benefits advertisers and the media firm. The impact on total welfare is ambiguous.

5.1 Advertising Quantity

Proposition 5. *Suppose that allowing consumers to pay to remove advertisements is optimal. Then, advertising quantity is increasing in the annoyance of ads and is higher than when the media firm is purely ad-based.*

Proof. Follows by a straightforward comparison of advertising quantity in propositions 2 and 3 and by inspection of advertising quantity in proposition 3. □

The first result of proposition 5 may be surprising. Intuitively, one might think that if advertisements generate more disutility through their impact on quality, advertising quantity should be decreased. However, a higher impact on utility is desirable for the media firm since this decreases the value of the ad-based version. Further, it increases the marginal impact of advertising quantity on quality. This implies that the optimal advertising quantity should be increased by decreasing the price for ad-space. Hence, as γ increases so does advertising quantity.

The second result that advertising quantity is high when consumers can pay to remove advertisements is due to the fact that the media firm has incentives to make paying to remove advertisements as attractive as possible to consumers. This can be done by reducing the price for removing advertisements or by decreasing the price for advertising space (thereby increasing the advertisement quantity). At the optimum, doing both is optimal, and thus, advertising quantity increases as the price for ad-space falls.

This result yields a testable implication of the model. When firms allow consumers to pay to remove advertisements, the advertisement quantity should be higher when this option is not available (or the existing ads should be more annoying). There seems to be some anecdotal evidence of this result. The option to pay to get rid of advertisements on *slashdot.org* was introduced when traffic increased (Slashdot.org, 2008). As mentioned by Prasad et al. (2003), *Slashdot.org* increased the number of advertisements displayed in connection with introducing the option. The same seems to be true for *Gamespot.com.* Compared to other sites operated by CNET Networks, *Gamespot.com* seems to have the most advertisements. It is one of two sites in their portfolio that allows consumers to pay to get rid of the advertisements (Gamespot.com, 2008).

5.2 The Distribution of Surplus

In this subsection, I compare the change in the distribution of the surplus among advertisers, the media firm and consumers. Specifically, I am interested in considering the implications on the surplus distribution of a shift from being ad-based to allowing consumers to pay to remove advertisements. As emphasized in the introduction, newly available technologies make it easier for traditionally ad-based firms to charge consumers for a fee-based version of their product. There also seems to have been an increase in the practice of offering software services in ad-based versions (usually to consumers) and paid versions (usually to corporations). This may partly be due to the increasing presence of Internet based software. By comparing the distribution of surplus across the different ranges in my model, I can analyze how these new technologies may have an impact on the consumer-, advertiser- and producer surplus.

Given optimal prices, the consumer surplus can be split into the surplus to consumers consuming the fee-based version and consumers consuming the ad-based version:

$$CS^F(\theta_c, p_c) = \int_{\theta_c}^{1} \theta v - p_c d\theta \tag{12}$$

$$CS^A(\theta_c, p_c, a) = \int_{0}^{\theta_c} \theta(v - \gamma a) d\theta \tag{13}$$

while surplus left to advertisers can be denoted

$$AS(\sigma_a, p_a, n) = \int_{\sigma_a}^{1} \sigma snN - p_a d\sigma \tag{14}$$

Total surplus is defined as $TS = CS^F + CS^A + AS + \Pi$. To focus on the shift to allowing consumers to pay to remove advertisements, I assume that v is sufficiently low so that shifting to a fully fee-based business model is not optimal. By substituting optimal parameter values from propositions 2 and 3 and comparing surpluses, the following proposition can be shown.

Proposition 6. *A shift from being ad-based to allowing consumers to pay to remove advertisements results in higher profits for the media firm, a greater surplus to advertisers and a decrease in the consumer surplus. The impact on the total surplus is ambiguous.*

Proof. The consumer and advertiser surplus if the media firm allows consumers to pay to remove advertisements is given by:

$$CS^A_{F+A} = N\int_0^{\theta_c^*} \theta(v-a^*)d\theta = N\frac{(s-2\gamma)(2\gamma(s+v)^2-3sv(4\gamma+s)}{54s\gamma^2} \quad (15)$$

$$CS^F_{F+A} = N\int_{\theta_c^*}^1 \theta v - p_c^* d\theta = N\frac{(\gamma+s)^2(3sv-\gamma(\gamma+s))}{54s\gamma^2} \quad (16)$$

$$AS_{F+A} = \int_{\sigma_a^*}^1 \sigma s N n^* - p_a^* d\sigma = N\frac{(s+\gamma)^3}{54s\gamma} \quad (17)$$

where $\theta_c^* = \frac{s+\gamma}{3\gamma}$, $\sigma^* = \frac{2s-\gamma}{3s}$, $a^* = \frac{1}{3}+\frac{\gamma}{3s}$, $p_c^* = \frac{(s+\gamma)}{9s}$ and $p_a^* = N\frac{1}{9}(s+\frac{2s}{\gamma}-\gamma)$. The surplus for these consumers under the ad-based business model, i.e. with $\theta_c^* = \frac{s+\gamma}{3\gamma}$, $\sigma^* = \frac{2s-\gamma}{3s}$, $a^* = \frac{1}{2}$ and $p_a^* = N\frac{s}{2}$, would have been:

$$CS^A_{A'} = N\int_0^{\theta_c^*} \theta(v-a^*)d\theta = N\frac{(g+s)^2(2v-\gamma)}{36\gamma^2} \quad (18)$$

$$CS^F_{A'} = N\int_{\theta_c^*}^1 \theta(v-a^*)d\theta = N\frac{(2\gamma-s)(4\gamma+s)(2v-\gamma)}{36\gamma^2} \quad (19)$$

where the sum of these two is $N\frac{(2v-\gamma)}{4}$ and the total advertiser surplus under the ad-based business model is $AS_A = N\frac{s}{8}$.

Consider the following differences in surplus. Let $\Delta CS^F = CS^F_{F+A} - CS^F_{A'}$ denote the difference in surplus for consumers who choose to pay to remove advertisements when this option is available to them. Let $\Delta CS^A = CS^A_{F+A} - CS^A_{A'}$ be the difference in surplus for consumers who still choose to use the advertising based version when the option to pay to remove advertisements is available. Denote the difference in advertiser surplus by $\Delta AS = AS_{F+A} - AS_A$ and the difference in firm profits by $\Delta\Pi = \Pi_{F+A} - \Pi_A$. Let r be the ratio $\frac{s}{\gamma}$. Then, the differences in surplus can be expressed as

$$\Delta CS^F = \frac{(r-2)^3 N\gamma}{108r} \quad (20)$$

$$\Delta CS^A = \frac{(r-2)(1+r)^2 N\gamma}{108r} \quad (21)$$

$$\Delta AS = \frac{(r-2)^2(1+4r)N\gamma}{216r} \quad (22)$$

$$\Delta\Pi = \frac{(r-2)^2(1+4r)N\gamma}{108r} \quad (23)$$

The difference in advertiser surplus and firm profits is positive for $r \in]\frac{1}{2}, 2[$. The difference in consumer surplus is negative for both consumer segments. The effect on total welfare is equal to $\Delta W = \Delta AS + \Delta CS^F + \Delta CS^A + \Delta\Pi = \frac{1}{216r}M\gamma(r-2)(4+r(16r-25))$. The effect on total welfare is ambiguous and depends on $sign\{4+r(16r-25)\}$. □

Consider the change in the surplus distribution when paying to remove advertisements is introduced. The media firm obviously benefits, otherwise it could remain purely ad-based. Perhaps surprisingly, consumers are worse off when they have the option to pay to remove advertisements. Consumers who choose to pay to remove advertisements are worse off because the price they are forced to pay causes more disutility than did advertising when the firm was ad-based. They are still willing to pay though, since the quantity of ads in the ad-based version is increased when the option to pay to remove advertisements is available. Since there is an increase in ad-quantity, consumers using the free version when both options are available are also worse off. These consumers now have to put up with a higher amount of advertisements than under the purely ad-based business model.[20] Finally, a higher amount of advertising implies that the price for ad-space must decrease causing advertisers to benefit.

The impact on total welfare depends on the relative sizes of gains to the media firm and advertisers, versus the losses in consumer surplus. The advertiser surplus plays a key role here because it captures some of the benefits of informational advertising. However, it is not sufficiently high to compensate for losses in consumer surplus for all parameter ranges. Naturally, there is a question of which measure of total welfare is of importance. If total welfare is measured as the sum of consumer-, media firm and advertiser surplus, the overall implication is ambiguous. However, if consumer surplus is the relevant measure for total welfare, then there is an unambiguous decrease in welfare.[21]

To summarize, this section showed that advertising quantity is higher when consumers can pay to remove advertisements as compared to when they cannot. Further, advertising quantity may be increasing in the annoyance of advertisements. Shifting to a business model of allowing consumers to pay to remove advertisements harms consumers but benefits advertisers and the media firm. The impact on total welfare is ambiguous.

6 Conclusion

In this paper, I have showed that a business model of allowing consumers to pay to remove advertisements is more likely to be optimal when the quality of the media firm's product is low, the annoyance of advertisements is high, and advertisers' profit margins are low. Further, the media firm may benefit from an increase in the annoyance of advertisements. Advertising quantity is higher when consumers can pay to remove advertisements as compared to when they cannot and advertising quantity may be increasing in the annoyance of advertisements (this offers a testable implication of the model). Shifting to a business model of allowing consumers to pay to remove advertisements harms consumers but benefits advertisers and the media firm. The impact on total welfare is ambiguous.

Understanding what impact price discrimination may have on advertising quantity and the distribution of surplus may be of importance in discussions related to policy issues.

[20]Note that none of them choose not to use the product since $v > \gamma a$ is imposed. If we relax this assumption, a potential positive effect on the consumer surplus of allowing consumers to pay to remove ads could be due to the fact that some consumers who really dislike advertisements did not use the product when it was ad-based but would use it if they could pay to remove advertisements.

[21]The result that consumers are harmed and that the impact on overall welfare is ambiguous is in line with the analyses of Holden (1993) and Hansen and Kyhl (2001).

An increasing percentage of advertising budgets is spent on advertising online and new technologies permitting consumers to pay to remove advertisements are emerging. Hence, the results of this analysis may be of interest to policy makers.

In terms of further research, generalizing the model by introducing competition among media firms is an obvious next step.[22] Further possible extensions would be to incorporate advertisers that care about which type of consumers they reach and/or to allow consumers to receive informational benefits from viewing advertisements. Finally, a testable implication of the model is that the advertising quantity should be higher when the option of paying to remove advertisements is available to consumers. Empirically testing this implication might be of interest.

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Open Versus Closed Platforms

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Abstract

This paper studies an industry where firms can choose to provide open or closed platforms. Open, as opposed to closed, platforms are extendable so that third-party producers can develop extensions for them. Building on a two-sided market model, I show that firms might prefer to commit to keeping their platforms closed despite the fact that opening the platform is costless and open platforms are more valuable to consumers. The reason is that opening the platform may lead to intensified competition for consumers.

Keywords: Platforms; Software; Two-sided markets.

JEL Codes: D40; D42; D43; L10; L12; L13; L14.

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1 Introduction

Why are some platforms open to third-party development while others are closed? In this paper, I take a two-sided market approach and highlight that the choice may involve a trade-off between benefits from an open platform and intensified competition for consumers. Opening the platform is beneficial because giving consumers access to third-party extensions raises the value of the platform. Further, open platforms can profit from selling access to the platform to third-parties. But because opening the platform intensifies competition for consumers, firms might prefer to commit to keeping their platforms closed.

The choice between supplying an open versus a closed platform is relevant in a number of markets. For example, operating systems for modern personal computers are prime examples of open platforms. Apple's OS X, Microsoft's Windows Vista and various versions of Linux all allow for, and encourage, application development. The same holds for video game consoles. As of 2008, the three large consoles on the market (the Xbox360, the Playstation 3 and the Wii) are all sold as open platforms with third-parties developing games for the consoles. But there also exists a sea of cheaper closed consoles that come with one or several pre-installed games (such as Sudoku or Tetris).

In some markets the same firm might provide both open and closed platforms. For example, high-end phones usually already have an operating system installed that allows for third-party applications.[1] The Nokia N95 comes with the S60 software that permits users to install software from third-party application developers. Cheaper mobile phones, such as the Nokia 1600, are often closed and no applications can be installed. Interestingly, when Apple entered the mobile phone market in June 2007 with the iPhone, they entered with a closed platform. Native third-party application development was impossible for the phone, thereby upsetting developers that had become used to open high-end phones. Apple, however, responded by releasing a software development kit for the iPhone in June 2008, which implied that third-party development is now possible.[2]

In some markets, platforms shift from open to closed over time. In enterprise software, for example, there seems to have been a shift towards closed platforms. The following account is from Arora and Bokhari (2007): "In enterprise software, for instance, SAP offers a closed product (an integrated suite, to use the industry term), with various application modules designed to work with the basic SAP enterprise resource planning (ERP) platform. Instead, until recently, users could opt for an Oracle database platform, using applications from Peoplesoft for human resources, JD Edwards for financial management, Siebel for customer relationship management and so on. In the last couple of years, all of these companies were acquired by Oracle, and it is likely that in the future, it will offer an integrated suite as well, so that we might see only competing closed systems in this market."

[1] A mobile phone can be seen as a platform in a two-sided market since the operating system that it runs on it allows users of the phone and third-party developers that write applications for the phone to interact.

[2] http://www.apple.com/pr/library/2008/03/06iphone.html. Accessed August 2008.

I am naturally not the first to analyze the choice between supplying an open versus a closed platform.[3] Kende (1998) compares the profitability of open versus closed systems. He departs from the literature on aftermarkets.[4] A firm can sell an open platform for a high price and encourage competition and cheap provision of extensions by third-parties in an aftermarket when consumers have already bought the platform. Alternatively, the firm could sell a cheap closed platform and itself provide extensions at a monopoly price in the aftermarket. Kende (1998) shows that an open system is more profitable when demand for the system is more elastic, secondary component variety is valued more highly and when the main component has a large share of consumers' budget.

Matutes and Regibeau (1988) study configurations with mix and matching of components.[5] Compatibility (open platforms) allows consumers to mix and match components from two competing firms. Incompatibility (closed platforms) forces consumers to buy both components from the same firm. The authors show that industries should tend towards compatibility, because compatibility shifts the industry demand curve upwards and relaxes price competition.

Church and Gandal (2000) introduce a taste for variety in secondary components in their study of hardware and software systems. Closing the system implies integration into the secondary component and enforcing incompatibility with the other component. The profitability of closing the system depends on a trade-off between profits from selling software produced in-house, and profit increases from selling more hardware when there is a larger variety of software provided by third-parties.

Arora and Bokhari (2007) build a dynamic model of open versus closed systems. They emphasize that firms may differ in their costs of producing different components. Open firms can specialize in producing one component while closed firms cannot and must produce both components. In the long run, the trade-off is between diseconomies of scope (in favor of open systems) and costs of transacting across firm boundaries (in favor of closed systems).

On a theoretical basis, and in contrast to the above mentioned papers, I build on the existing literature on two-sided markets.[6] I start from a stylized two-sided market model that builds on Armstrong (2006) and I endogenize the choice of operating in a one-sided (closed) or two-sided (open) market. Much of the early literature on two-sided markets focuses on solving the problem of how much to charge each side. Related to comparing one and two-sided markets, there has been some work on the difference between operating as a merchant versus operating as a platform. According to Hagiu (2007a), the main difference is that a merchant takes full possession of the content, whereas a platform leaves control

[3]The concept of open and closed platforms has been interpreted in different ways in the literature. Schiff (2003) analyzes open and closed systems of two-sided networks, referring to compatibility between two platforms (e.g. if applications developed for one platform work with the other). Hagiu (2007b) analyzes open versus proprietary platforms, where an open platform indicates that prices are zero on both sides.

[4]See also Shapiro (1995) and Borenstein and MacKie-Mason (2000).

[5]See also Economides (1989).

[6]See, for example, Rochet and Tirole (2003), Caillaud and Jullien (2003), Rochet and Tirole (2006), Hagiu (2006), Choi (2006) and Armstrong (2006).

over the sale to sellers and simply intermediates the transaction. There is also related work on exclusivity in two-sided markets by Hagiu and Lee (2007) and Lee (2007). In their model, a content provider joins one or both platforms depending on whether the content is exclusive or not. In contrast, I compare the platforms' choice between allowing third-parties or not.[7]

In taking the two-sided market route, my approach is different from that of Kende (1998) in that I assume away the central hold-up problem in the aftermarket literature. Instead, I focus on the ability of firms to charge (or subsidize) third-parties for the right to develop applications for the platform. Adding this dimension, the firms can directly profit from selling rights to develop for the platform. They also have the ability to subsidize developers to encourage application development. I mainly differ from the components versus systems approach in Matutes and Regibeau (1988), Church and Gandal (2000) and Arora and Bokhari (2007) by analyzing atomistic producers of secondary components instead of two (or more) components produced by the same (or different) firms. I place heavy emphasis on the existence of cross-group externalities between consumers and application developers. Further, I completely "black box" the pricing decision of application developers. My approach has the advantage of emphasizing cross-group externalities and platform pricing to internalize them. The drawback is that I assume away potentially important strategic interactions between the price of the platform and the price of applications set by application developers.

2 The Model

I study a two-stage duopoly model of a two-sided market where software platforms connect consumers with third-party application providers. There are two platforms, $k \in \{1, 2\}$, each with the same intrinsic value v. The value of any applications developed in-house by the platform is also included in v. The number of these applications is exogenous and independent of the platform being open or closed. For example, the same basic set of applications (such as a calendar, a phone book, an alarm clock, a simple game) bundled with high-end open phones is also often available on closed low-end phones. When Apple introduced the closed iPhone, the set of built-in applications resembled the basic set of applications bundled with other competing high-end phones.

The platforms can be open, in which case they connect consumers with application developers, or they can be closed and simply sell the platform of value v to consumers. If open, platforms can set a fee (or subsidy) for the right to develop an application. Finally, the costs for opening the platform are zero. Fixed costs are sunk and marginal costs zero. Consumers only buy one platform, but application developers may develop for any or both of the open platforms.

[7] One of the results in Hagiu and Lee (2007) is that platforms might want to give up control rights over pricing content in order to relax competition. This result is perhaps most closely related to this paper as platform here might want to give up all gains (from consumers and/or from third-parties) in order to relax competition.

2.1 Consumers

Consumers are uniformly distributed on the unit interval with the platforms located at the endpoints of the interval. The intrinsic value of the platforms, v, is sufficiently large for the market to be completely covered.[8]

In the eyes of consumers, the platforms only differ in price and the number of applications available. A consumer denoted by i receives utility

$$u_{i1} = (v - tx_i) + bn_{a1} - p_1, \tag{1}$$

if buying platform 1 and utility

$$u_{i2} = (v - t(1 - x_i)) + bn_{a2} - p_2, \tag{2}$$

if buying platform 2. The number of applications available at platforms 1 and 2 are given by n_{a1} and n_{a2}. The parameter $b > 0$ measures the additional value of the platform for each available third-party application. Platform prices are p_1 and p_2. The transportation cost parameter, t, measures the intensity of competition.

2.2 Application Developers

The application developers are independent monopolists. They are treated as atomistic and are uniformly distributed on the unit interval, $y \in [0, 1]$.

Developers are heterogeneous in terms of fixed costs for coming up with a business idea, setting up shop and developing an application. An application developer indexed by y_j has fixed costs equal to fy_j for developing an application.

Each application developer is able to extract an expected profit of $a > 0$ from each consumer purchasing the platform. These profits are generated from sources such as selling advertising space or increased sales from complementary products.

Application developers are allowed to multi-home. This means that they may develop applications for both platforms. If both platforms are open, application developers make the decision to develop for one platform independently of the decision to develop for the other platform. Thus, there is no direct competition between the firms for developers. A firm can attract more developers by either reducing the price of the platform, thereby selling to more consumers, or by reducing the fee or increasing the subsidy for application development. Application developers must pay the fixed development cost twice if they wish to supply an application for both platforms.

Conditional on the number of consumers at each platform, an application developer j

[8]The condition needed when both platforms are closed is $v > \frac{3t}{2}$. When both firms provide open platforms the condition is $v > \frac{6ft - a^2 - 3ab}{4f}$. When one platform is closed and the other is open, the conditions are $abf(9t-4v) > a^3b + f(6ft(3t-2v) + b^2v) + a^2(b^2 + f(v-3t))$ and $f(b^2(3t-v) + 6ft(2v-3t)) > a(a^2b + 2ab^2 + b^3 - 3aft - 12bft + (a+4b)fv)$.

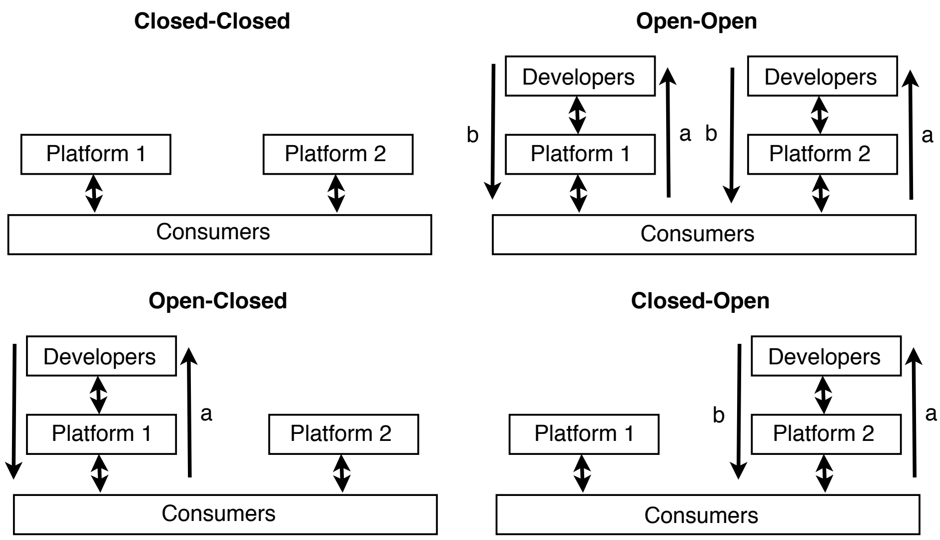

Figure 1: In stage 1 firms choose between providing an open or providing a closed platform. Their choices give rise to these sub-games in stage 2.

has profits equal to

$$\pi_{jk} = an_{ck} - fy_j - s_k \tag{3}$$

from each platform $k \in \{1, 2\}$. The costs of developing applications are sufficiently high to ensure that some developers always stay out of the market.[9]

Parameter s_k denotes the fee or subsidy imposed or handed out by the platform. If s is positive, it represents a fee that must be paid for the right to develop an application. An example is a fee that must be paid for an application development kit needed to create the application. If s is negative it is a subsidy. It can then be any type of action by the firm operating the platform that reduces the costs of developing an application, such as training, subsidized conferences and free extensive documentation of interfaces.

2.3 Timing

- In stage 1, firms simultaneously decide whether to be open or closed. Figure 1 illustrate possible outcomes.
- In stage 2, firms observe the choice made by the rival. Then, they simultaneously set prices to consumers. Firms providing open platforms also set the fee or subsidy to application developers. Consumers and developers then observe prices and the fees or subsidies. They form rational expectations regarding participation of the opposite group. Then, consumers buy the platform yielding the highest utility and developers decide separately for each platform if they should develop for the platform.

[9]The assumptions needed are $f > \frac{a+b}{4}$ when the platforms are open and $f(a^2+4ab+b^2+3(a+b-4f)t) < ab(a+b))$ when one platform is open and the other is closed.

This timing captures the fact that the choice of providing a closed or an open platform is more long term than the choice of prices and fees (subsidies). It allows firms to commit to providing an open or a closed platform before setting prices and fees.

In what follows, I solve this game by backwards induction. I look for pure strategy sub-game perfect Nash equilibria. I start by analyzing pricing in the second stage of the game. I consider separately all four sub-games outlined in figure 1. Then, I move back to the first stage of the game and analyze the choice between providing an open or a closed platform.

3 Analysis

3.1 Stage 2: Closed-Closed

When both platforms are closed, the setup reduces to the standard Hotelling model with firms at both endpoints of the unit interval. For the consumer who is indifferent between purchasing the platform from firm 1 or firm 2, $v - tx_i - p_1 = v - (1-t)x_i - p_2$ holds. Then, demand for firm 1's platform is equal to $n_{c1} = \frac{1}{2} + \frac{p_2 - p_1}{2t}$. Demand for firm 2's platform is equal to $n_{c2} = 1 - n_{c1}$. The firms simultaneously set price to maximize

$$\pi_{kCC} = p_k n_{ck}. \tag{4}$$

This results in equilibrium prices of $p^*_{kCC} = t$, and profits of $\pi^*_{kCC} = \frac{t}{2}$. The second-order conditions, $-\frac{1}{t} < 0$, are satisfied. Prices and profits are decreasing in the intensity of competition between firms.

3.2 Stage 2: Open-Open

The consumer who is indifferent between purchasing platform 1 and purchasing platform 2 is now located at the x_i that satisfies $v + bn_{a1} - tx_i - p_1 = v + bn_{a2} - (1-t)x_i - p_2$. Demand for firm 1's platform conditional on the number of applications at each platform is then equal to $n^{cond}_{c1} = \frac{1}{2} + \frac{bn_{a1} - bn_{a2}}{2t} + \frac{p_2 - p_1}{2t}$. Demand for firm 2's platform conditional on the number of applications at each platform is $n^{cond}_{c2} = 1 - n^{cond}_{c1}$. The developer who is indifferent between developing and not developing an application for platform k is located at $y_j = \frac{an_{ck} - s_k}{f}$. Demand for developing applications for platform k conditional on the number of consumers purchasing each platform is then $n^{cond}_{ak} = \frac{an_{ck} - s_k}{f}$. To obtain demands as functions of prices on both sides of the market, I simultaneously solve equations

$n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$, $n_{a1} = n_{a1}^{cond}$ and $n_{a2} = n_{a2}^{cond}$ to obtain

$$n_{c1}(p_1, p_2, s_1, s_2) = \frac{b(s_2 - a - s_1) + f(p_2 - p_1 + t)}{2(ft - ab)}, \quad (5)$$

$$n_{c2}(p_1, p_2, s_1, s_2) = \frac{b(s_1 - a - s_2) + f(p_1 - p_2 + t)}{2(ft - ab)}, \quad (6)$$

$$n_{a1}(p_1, p_2, s_1, s_2) = \frac{a(b(s_1 + s_2) + f(p_2 - p_1 + t)) - a^2 b - 2fs_1 t}{2f(ft - ab)}, \text{ and} \quad (7)$$

$$n_{a2}(p_1, p_2, s_1, s_2) = \frac{a(b(s_1 + s_2) + f(p_1 - p_2 + t)) - a^2 b - 2fs_2 t}{2f(ft - ab)}. \quad (8)$$

Firms simultaneously set prices, p_k, to consumers and the fees (subsidies) to application developers, s_k, to maximize

$$\pi_{kOO} = p_k n_{ck}(p_1, p_2, s_1, s_2) + s_k n_{ak}(p_1, p_2, s_1, s_2). \quad (9)$$

Equilibrium prices are

$$p_{kOO}^* = t - \frac{a(a + 3b)}{4f} \text{ and } s_{kOO}^* = \frac{a - b}{4}, \quad (10)$$

and platform profits are

$$\pi_{kOO}^* = \frac{t}{2} - \frac{a^2 + 6ab + b^2}{16f}. \quad (11)$$

The second-order conditions, $-\frac{f}{ft-ab} < 0$, $-\frac{2ft-ab}{f(ft-ab)} < 0$, and $\frac{8ft-a^2-6ab-b^2}{4(ab-ft)^2} > 0$ are satisfied for $4ft - (a + b)^2 > 0$.

Firms balance the price to consumers with fees (or subsidies) to application developers so as to best internalize cross-group externalities. Application developers are subsidized if the valuation of applications by consumers is sufficiently large in relation to developers' profits from reaching an additional consumer (if $b > a$).

As noted by Armstrong (2006), profits from the multi-homing side (the application developer side) are competed away on the single-homing (consumer) side of the market. The reason is that the competition for consumers is intensified when platforms are open. A cut in the price leads to more consumers buying the platform. It also attracts more application developers because more consumers have bought the platform. Both platforms then have strong incentives to cut price. These incentives are increasing in the size of cross-group externalities and decreasing in the costs of developing applications (because it becomes easier to attract developers). Hence, profits (and prices) are increasing in the costs of developing applications and decreasing in the size of the cross-group externalities.

3.3 Stage 2: Open-Closed and Closed-Open

Assume that firm 1 has the open platform and firm 2 has the closed platform. The formulas for the reverse case can easily be obtained by renaming the platforms.

Conditional on the number of applications developed for platform 1, the consumer who is indifferent between platforms is located at the x_i that satisfies $v + bn_{a1} - tx_i - p_1 = v - (1-t)x_i - p_2$. Demand for platform 1 conditional on the number of application developers that develop for platform 1 is $n_{c1}^{cond} = \frac{1}{2} + \frac{bn_{a1}}{2t} + \frac{p_2 - p_1}{2t}$. Demand for platform 2 conditional on the number of application developers that develop for platform 1 is $n_{c2}^{cond} = 1 - n_{c1}^{cond}$. The developer who is indifferent between developing for platform 1 and not developing is located at $y_j = \frac{an_{c1} - s_1}{f}$. Demand for developing applications for platform 1 conditional on the number of consumers purchasing platform 1 is then $n_{a1}^{cond} = \frac{an_{c1} - s_1}{f}$. To obtain demands as functions of prices on both sides of the market, I simultaneously solve equations $n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$ and $n_{a1} = n_{a1}^{cond}$. This gives

$$n_{c1}(p_1, p_2, s_1) = \frac{bs_1 + f(p_1 - p_2 - t)}{ab - 2ft}, \tag{12}$$

$$n_{c2}(p_1, p_2, s_1) = \frac{ab - bs_1 - f(p_1 - p_2 + t)}{ab - 2ft}, \text{ and} \tag{13}$$

$$n_{a1}(p_1, p_2, s_1) = \frac{a(p_1 - p_2 - t) + 2s_1 t}{ab - 2ft}. \tag{14}$$

Firm 1 sets the price to consumers and the fee (or subsidy) to application developers to maximize

$$\pi_{1OC} = p_1 n_{c1}(p_1, p_2, s_1) + s_1 n_{a1}(p_1, p_2, s_1). \tag{15}$$

Firm 2 simultaneously sets the price to consumers to maximize

$$\pi_{2OC} = p_2 n_{c2}(p_1, p_2, s_1). \tag{16}$$

Equilibrium prices are

$$p_1^* = \frac{(4ft - a(a+b))(3ft - ab)}{f(12ft - a^2 - 4ab - b^2)}, \tag{17}$$

$$s_1^* = \frac{(a-b)(3ft - ab)}{12ft - a^2 - 4ab - b^2}, \text{ and} \tag{18}$$

$$p_2^* = \frac{(6ft - (a+b)^2)(2ft - ab)}{f(12ft - a^2 - 4ab - b^2)}. \tag{19}$$

Platform profits are

$$\pi_{1OC}^* = \frac{(8ft - (a+b)^2)(ab - 3ft)^2}{f(a^2 + 4ab + b^2 - 12ft)^2}, \text{ and} \tag{20}$$

$$\pi_{2OC}^* = \frac{((a+b)^2 - 6ft)^2(2ft - ab)}{f(a^2 + 4ab + b^2 - 12ft)^2}. \tag{21}$$

The second-order conditions $-\frac{2f}{2ft - ab} < 0$, $-\frac{4t}{2ft - ab} < 0$ and $\frac{8ft - (a+b)^2}{(ab - 2ft)^2} > 0$ are satisfied for $4ft - (a+b)^2 > 0$. By reversing the identities of the platforms, we can get profits under the outcome Closed-Open. These profits are $\pi_{1CO}^* = \pi_{2OC}^*$ and $\pi_{2CO}^* = \pi_{1OC}^*$. Application

		Firm 2	
		C	O
Firm 1	C	$(\pi^*_{1CC}, \pi^*_{2CC})$	$(\pi^*_{1CO}, \pi^*_{2CO})$
	O	$(\pi^*_{1OC}, \pi^*_{2OC})$	$(\pi^*_{1OO}, \pi^*_{2OO})$

Figure 2: The simultaneous game played in stage 1.

developers are subsidized if $b > a$. The size of cross-group externalities and the costs of developing applications can either increase or decrease profits. The reason is that while cross-group externalities benefit the platform, they also lead to intensified competition for consumers.

3.4 Stage 1: Open or Closed?

The firms simultaneously decide if third-parties should be able to develop for their platform. The game played in stage 1 is summarized in figure 2. By solving the first stage, we can obtain the following proposition.

Proposition 1. *For sufficiently large differences in cross-group externalities, both firms provide open platforms. They are trapped in a prisoner's dilemma. If the difference in cross-group externalities is sufficiently small, both firms provide closed platforms. For intermediate differences in cross-group externalities, one platform is open and one is closed.*

Proof. First, assume that it is desirable for firm 1 to offer an open platform if firm 2 offers a closed platform. Then $\pi^*_{1OC} > \pi^*_{1CC}$ or $\frac{(8ft-(a+b)^2)(ab-3ft)^2}{f(a^2+4ab+b^2-12ft)^2} > \frac{t}{2}$. Simplifying, using $4ft - (a+b)^2 > 0$, leads to the following condition $2a^2b^2 + (a^2 - 6ab + b^2)ft > 0$. Note that this condition holds if $a^2 - 6ab + b^2 > 0$ or equivalently, if $(a-b)^2 - 4ab > 0$ (there is a sufficient difference in cross-group externalities). Assuming that $a^2 - 6ab + b^2 > 0$, it is possible to show that $\pi^*_{1OO} > \pi^*_{1CO}$ or that $\frac{8ft-a^2-6ab-b^2}{16f} > \frac{((a+b)^2-6ft)^2(2ft-ab)}{f(a^2+4ab+b^2-12ft)^2}$. Then firm 1 has a dominant strategy to open the platform. This also holds for firm 2. Hence, the pure strategy Nash equilibrium is for both firms to provide open platforms. The equilibrium is shown in area 1 in figure 3. Since $a^2 + 6ab + b^2 > 0$, it must be that $\pi^*_{1CC} > \pi^*_{1OO}$ and the game is a prisoner's dilemma.

Second, now suppose that $2a^2b^2 + (a^2 - 6ab + b^2)ft > 0$, but that $a^2 - 6ab + b^2 < 0$ (so ft is small). Then $\pi^*_{1OC} > \pi^*_{1CC}$, but it need not be that $\pi^*_{1OO} > \pi^*_{1CO}$. If, instead, $\pi^*_{1OO} < \pi^*_{1CO}$, the game has two pure strategy Nash equilibria. Either firm 1 provides an open platform and firm 2 provides a closed platform or the reverse holds. Equilibria of this type must lie in area 3 in figure 3, but area 3 also contains parameter combinations resulting in an equilibrium characterized by both platforms being open.

Third, now assume that it is desirable for firm 1 to provide a closed platform if firm 2 provides a closed platform. Then, $2a^2b^2 + (a^2 - 6ab + b^2)ft < 0$ and it is possible to use this to show that $\pi^*_{1CO} > \pi^*_{1OO}$. Firm 1 has a dominant strategy to remain closed. This

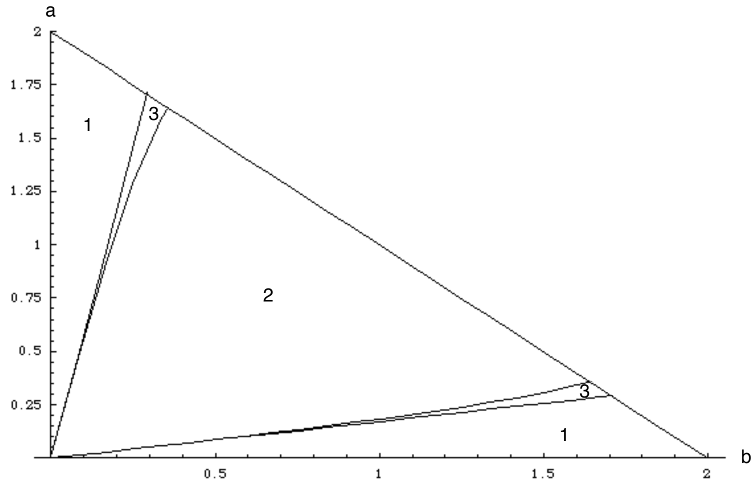

Figure 3: Equilibrium regions for $f = t = 1$. The line from (0,2) to (2,0) corresponds to $4ft - (a+b)^2 = 0$, the line separating areas 1 and 3 to $(a-b)^2 - 4ab = 0$ and the line separating areas 2 and 3 to the equation $2a^2b^2 + (a^2 - 6ab + b^2)ft = 0$. Varying f or t scales the picture.

also holds for firm 2 and the pure strategy Nash equilibrium is for both firms to provide closed platforms. This equilibrium is characterized by parameter combinations in area 2 in figure 3. $\square$

The proposition highlights that firms may have a dominant strategy to remain closed, despite the fact that opening the platform is free and consumers value an open platform more highly than a closed platform. The reason is that competition is intensified when platforms are open. All else equal, a given price cut to consumers when platforms are open attracts more new consumers as compared to when platforms are closed because the price is lower and the platform value higher.

To see this formally, we can examine the best response functions of firm 1. The best response functions for price for firm 1 when its platform is closed are

$$p_1(p_2)_{CC} = \frac{t+p_2}{2}, \text{ and} \tag{22}$$
$$p_1(p_2, s_2)_{CO} = \frac{t+p_2}{2} - \frac{b(a-s_2)}{2f}. \tag{23}$$

When firm 1 provides an open platform, the best response functions are

$$p_1(s_1, p_2)_{OC} = \frac{t+p_2}{2} - \frac{(a+b)s_1}{2f}, \text{ and} \tag{24}$$
$$p_1(s_1, p_2, s_2)_{OO} = \frac{t+p_2}{2} - \frac{(a+b)s_1}{2f} - \frac{b(a-s_2)}{2f}. \tag{25}$$

Studying these, we can see that because $\frac{b(a-s_2)}{2f} > 0$ in equilibrium, firm 1 has incentives to price more aggressively if firm 2 provides an open platform.[10] Hence, by committing to providing closed platforms, firms are able to reduce the intensity of competition for consumers.

In equilibrium, the effect on profits from opening the platform depends on a balance between a) benefits from an increase in the value of the platform and the possibility to profit from application developers and b) intensified competition for consumers.[11]

For a sufficiently similar to b, both firms have individual incentives to provide a closed platform. An open platform would lead to lower profits due to intense competition for consumers. This case is represented in area 2 in figure 3. If a is much larger than b, acquiring additional consumers is very profitable for the firm as the fee for the right to develop applications can be substantially increased. Even though competition for consumers is intensified with an open platform, the firm finds it profitable to open the platform because selling the rights to develop applications recoups losses from intensified competition for consumers.

If b is much larger than a, the ability to subsidize application developers so as to increase the value of the platform for consumers makes it profitable to provide an open platform. The value increase in the platform becomes sufficiently large so as to compensate for the effect of intensified competition. These two cases are represented by area 1 in figure 3. In both cases, the firms are trapped in a prisoner's dilemma. They would have been better off had they been able to collude in stage 1 on keeping the platforms closed.

For intermediate differences in a and b, it may be that platforms prefer to be open if the rival is closed and closed if the rival is open. In these cases profit increases from being open are enough to compensate for intensified competition only if the rival is closed, not if it is open. The reason is that competition is more intense when both firms are open than if only one firm is open. Area 3 in figure 3 contains such parameter combinations, but area 3 also contains parameter combinations where the equilibrium is for both firms to provide open platforms.

Finally, application development costs (f) and the intensity of competition between platforms (t) also affect the choice of providing an open versus a closed platform. Increased development costs for applications and decreases in the intensity of competition (increases in t) tend to make a closed platform more likely due to diminished benefits from cross-group externalities. This can be seen by noting that if ft is large and the difference in cross-group externalities small, it is more likely that $\pi^*_{1OC} < \pi^*_{1CC}$ and $\pi^*_{1CO} > \pi^*_{1OO}$ since it is more likely that $2a^2b^2 + (a^2 - 6ab + b^2)ft < 0$.

[10] Firm 1 is either more or less aggressive in pricing when open. If $b > a$, so that $s_1 < 0$ in equilibrium, firm 1 is less aggressive in pricing. If $b < a$, so $s_1 > 0$ in equilibrium, firm 1 is more aggressive in pricing.

[11] There is a difference between a standard quality increase of the platform and a quality increase induced by more application developers developing for the platform. The size of a standard quality increase does not depend on price, whereas the quality increase due to more application developers depends on prices on both sides of the market. Further, the total profits of the platform are the sum of profits from consumers and profits from application developers, so that increases in quality brought about by through having more application developers have a different effect on profits than standard quality increases.

4 Conclusion

Why are some platforms open to third-party development while others are closed? In this paper, I take a two-sided market approach and highlight that the choice may involve a trade-off between benefits from an open platform on one hand and intensified competition for consumers on the other. Providing an open platform is profitable because allowing third-party applications raises the value of the platform. A firm with an open platform can also either profit from selling the rights to develop applications, or subsidize developers to further increase the value of the platform. But opening the platform also leads to intensified competition. Hence, firms might prefer to commit to keeping their platforms closed despite the fact that opening the platform is costless and open platforms are more valuable to consumers.

I find three types of equilibrium configurations. Both platforms are open (and the firms are trapped in a prisoner's dilemma), both platforms are closed, or one platform is open and one is closed. The outcome depends on the relative difference in cross-group externalities, the intensity of competition for consumers and the cost for developing applications.

This stylized model can be extended in several directions. First, it was assumed that the market was completely covered on the consumer side. This implies that price cuts to consumers by the firms do not attract new customers. Neither do increases in quality from allowing third-party application development. Maintaining the assumption of a covered market thus biases the results in favor of closed platforms. However, the assumption does not change the fact that competition between open platforms is more intense than competition between closed platforms. Hence, the trade-off between intensified competition and a higher quality platform still remains.

Second, the current setup does not allow the firms to choose between in-house application development and outsourcing the development of applications to third-parties. I only consider the choice between allowing third-party application development or not. This is likely to bias the results in favor of open platforms, as opening the platform is the only way to increase the quality of the platform in the current model.

Third, it was assumed that third-party application developers had to incur the fixed cost of developing an application once for each platform. Once an application has been developed, however, it is likely that porting it to another platform is less expensive than rewriting it completely. Introducing this aspect into the model potentially significantly complicates the analysis. The reason is that in the current set up, each application developer decides on developing for one platform independently of her decision to develop for the other. As a consequence, the firms only compete directly for users and not for application developers, as the choice to develop for one is independent of the choice to develop for the other. If the costs for developing an application are conditional on whether the application was previously been developed, development choice becomes interdependent. The likely bias of this extension on the results is not clear and hence, is a good direction for future research.

Fourth, I have cast the model in the framework of software and hardware platforms. It could also apply to other two-sided markets where choosing between providing a one-sided or a two-sided platform is possible. In particular, the analysis could be adapted to study how magazines and TV stations are funded (see Kind, Nilssen, and Sorgard (2005)). A "closed" platform in this framework is a magazine or TV station without advertisements. An "open" platform has advertisements and is hence two-sided.

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Efficiency and the Provision of Open Platforms

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Abstract

Private firms may not have efficient incentives to allow third-party producers to access their platform or develop extensions for their products. Based on a two-sided market model, I discuss two reasons for this. First, a private firm may not be able to internalize all benefits from cross-group externalities arising with third-party extensions. Second, firms may have strategic incentives to shut out third-parties because it relaxes competition.

Keywords: Platforms; Two-sided markets; open versus closed.

JEL Codes: D40, L10.

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1 Introduction

Do private firms allow third-parties to access their platform or develop extensions for their product when it is socially desirable? This question has repeatedly been a concern for anti-trust authorities. For example, in 1955, the FCC in the United States agreed with the AT&T Bell System that an attachment to phones (the Hush-A-Phone) that helped reduce noise could not be marketed and sold independently, since it was a "foreign attachment" to the AT&T network. The FCC also concluded that all telephone equipment should be sold by the network operator. However, this decision was overturned on appeal by the D.C. Circuit.[1] In line with this appeal, the FCC later (in 1968) ruled that it should be possible to use another attachment, the Carterfone, on the AT&T Bell System network despite the fact that is was marketed by an independent company.

Another example is the anti-trust case Eastern Kodak Co. v. Image Technical Services, Inc. [2]. Kodak had excluded third-parties from being able to service the equipment they had sold. However, the Supreme Court ruled that external firms should be able to service Kodak's equipment.

In contrast to previous literature on this question, I take a two-sided market approach and propose two new reasons for why private incentives may be insufficient. First, a private firm may not be able to internalize all benefits from cross-group externalities arising when third-parties are involved. Second, firms may have strategic incentives to shut out producers of third-party extensions since closed platforms relax the competition for consumers.

My arguments are based on the recent literature on two-sided markets.[3] In two-sided markets, platforms serve as intermediaries for transactions between two groups of agents. The groups impose externalities on each other, and platforms should set a price to each group so as to best internalize these externalities. If we assume that the groups are consumers and third-party producers of extensions to the platform, we can analyze if platforms' incentives to deal with both groups, instead of just one, are socially efficient.

In section 2, I start out by setting up and discussing a simple monopoly model. I show that the social incentives to allow third parties access to the platform are likely to bo stronger than the private incentives. Then, I introduce competition between platforms in section 3 to show that platforms may inefficiently choose to commit to excluding third-parties because it relaxes the competition for consumers.

The literature on vertical relations in complementary markets is closely related to this paper.[4] The central "Chicago School" argument — see, for example, Bowman (1957)

[1] Hush-A-Phone Corp., 20 .F.C.C. 391, 420 (1955) (Decision), rev'd, 238 F2.d 266 (D.C. Cir. 1956)

[2] Eastern Kodak Co. v. Image Tech Services, 125 F3d. 1995 Ninth Circuit, 1997

[3] Seminal papers include Rochet and Tirole (2003), Caillaud and Jullien (2003), Rochet and Tirole (2006), Hagiu (2006) and Armstrong (2006).

[4] The literature is vast and, for example, includes analyses of tying complementary products (e.g. Whinston (1990), Carlton and Waldman (2002), Choi and Stefanadis (2001) and Nalebuff (2004)), innovation and integration in systems markets (e.g. Farrell and Katz (2000)), systems versus component competition (e.g. Matutes and Regibeau (1988), Economides (1989), Farrell et al. (1998), non-price discrimination

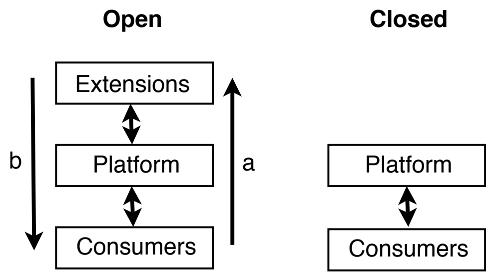

Figure 1: An open platform allows for third-party extensions. A closed one does not.

and Bork (1978) — states that private and social incentives for vertical integration in complementary markets should coincide. The reason is that a platform should have no incentives to vertically integrate into the supply of a complementary good, unless it is efficient, since it can always raise the price of the platform to internalize any potential surplus from the sale of the complementary good.

But the basic "Chicago School" argument can break down for several reasons. For example, as shown by Choi and Stefanadis (2001), integration may protect against entry by competitors, and as shown by Whinston (1990), integration might be used to leverage monopoly power into the other market.

Since I depart from the two-sided market literature, I use several assumptions commonly not used in this literature. First, I place a heavy emphasis on the existence of cross-group externalities between consumers and third-party extension providers. All else equal, increased participation by one group leads to more participation by the other. Second, firms in my model set a fee that third-partiy producers must pay for the right to develop an extension. This fee can also be negative, in which case it is a subsidy intended to encourage participation by third parties. Third, I consider several atomistic third-party extension providers that do not compete with each other and take the fee set by the firm as given. Further, the pricing decision of third-party extension providers is completely "blackboxed" and they are simply assumed to profit from interacting with consumers. The drawback of this approach is that I assume away potentially important strategic interactions between the price of the main product and the price of extensions set by third-party providers. The benefit is a new perspective emphasizing cross-group externalities and pricing to internalize these externalities.

2 All Benefits May Not be Internalized

2.1 Setup

A monopoly firm has developed a platform of quality $v > 0$. The platform can either be open or closed. An open platform grants third-party producers access to the platform so

(e.g. Economides (1998)), and intersystem competition and vertical foreclosure (e.g. Church and Gandal (2000)).

that they can develop extensions for it. A closed one does not, as illustrated by figure 1.

If open, the firm sets a fee (or subsidy) for the right to develop an extension. This fee is set simultaneously with the price for the platform. Consumers and extension providers then observe prices and fees, form rational expectations regarding the participation of the opposite group and, finally, simultaneously make their participation decisions. The marginal costs are zero, but the costs for providing an open platform instead of a closed platform are F.

Consumers are uniformly distributed over the unit interval, $x \in [0, 1]$ with the platform located at $x = 0$.[5] Consumers face a transportation cost t for each unit of distance travelled on the line. It is sufficiently large so that at the optimum, some consumers always choose to stay out of the market.[6]. Consumer i's location, x_i, then specifies her preference for the firm's platform and she receives utility $u_i = (v - tx_i) + bn_e - p$ if she purchases the platform.

The price of the platform is p and n_e denotes the number of third-party extensions available for the platform. Parameter $b > 0$ measures the additional value of the platform to the consumer for each third-party extension available.

The extension providers are independent monopolists. They are treated as atomistic and are uniformly distributed on the unit interval, $y \in [0, 1]$. They are heterogeneous in terms of coming up with a business idea, setting up shop and providing an extension. These costs are scaled by f. Each extension provider is able to extract an expected profit of $a > 0$ from each consumer purchasing the platform.

Extension provider j has total profits $\pi_j = an_c - fy_j - s$. If s is positive, it represents a fee that must be paid for the right to develop an extension. If s is negative it is a subsidy intended to encourage the development of extensions. Development costs are sufficiently large so that in equilibrium, some developers always choose to remain inactive.[7] Finally, the total number of consumers purchasing the platform is n_c.

2.2 Optimal Price and Fee/Subsidy

When the platform is closed, demand for the platform and the location of the consumer indifferent between buying and not buying the platform is $n_c(p) = x_{in} = \frac{1}{t}(v - p)$. The firm sets the price to maximize

$$\pi_C = pn_c. \tag{1}$$

The optimal price is $p^*_C = \frac{1}{2}v$ and the profits are $\pi^*_C = \frac{1}{4t}v^2$. The consumer surplus is $CS_C = \int_0^{x^*_{in}}(v - tx - p^*_C)dx = \frac{1}{8t}v^2$. The second-order condition $-\frac{2}{t} < 0$ is satisfied.

When the platform is open, conditional on the number of extensions available, the demand for the platform and the location of the consumer who is indifferent between

[5]The platform is located at $x = 0$ to allow for an easy extension to a duopoly setting in the next section. A more natural location might be $x = \frac{1}{2}$. As shown in the appendix, the results for this location remain unchanged.

[6]The assumption needed when the platform is closed is $t > \frac{v}{2}$ and when it is open is $t > \frac{(a+b)(a+b+v)}{4f}$.

[7]The assumption needed is $f > \frac{(a+b)^2}{4t-2v}$.

buying and not buying is $n_c^{cond}(p, n_e) = x_{in} = \frac{1}{t}(v + bn_e - p)$. Conditional on the number of consumers buying the platform, demand for developing extensions for the platform and the location of the extension provider who is indifferent between providing an extension and not providing one is $n_e^{cond}(s, n_c) = y_{in} = \frac{1}{f}(an_c - s)$. We can obtain consumer demand for the platform and demand for developing extensions for the platform as a function of p and s by simultaneously solving equations $n_c = n_c^{cond}(p, n_e)$ and $n_e = n_e^{cond}(s, n_c)$.

This gives $n_c = \frac{1}{ft-ab}(f(v-p) - bs)$ and $n_e = \frac{1}{ft-ab}(a(v-p) - st)$. The firm sets the price to consumers and the fee (subsidy) to extension providers to maximize

$$\pi_O = pn_c + sn_e. \tag{2}$$

The optimal prices are

$$p_O^* = \frac{v(2ft - a(a+b))}{4ft - (a+b)^2} \text{ and } s_O^* = \frac{vf(a-b)}{4ft - (a+b)^2}. \tag{3}$$

The profit, the consumer surplus and the total extension provider profit at these prices are

$$\pi_O^* = \frac{fv^2}{4ft - (a+b)^2}, \tag{4}$$

$$CS_O^* = \int_0^{x_{in}^*} (v + bn_e^* - tx - p_O^*)dx = \frac{2f^2tv^2}{((a+b)^2 - 4ft)^2}, \tag{5}$$

and

$$\Pi = \int_0^{y_{in}^*} (an_c^* - fy - s_O^*)dy = \frac{(a+b)^2fv^2}{2((a+b)^2 - 4ft)^2}. \tag{6}$$

The second-order conditions are $-\frac{2f}{ft-ab} < 0$ and $\frac{1}{(ab-ft)^2}(4ft - (a+b)^2) > 0$. I assume that $4ft - (a+b)^2 > 0$ to ensure that these hold. This states that the cross-group externalities are sufficiently small in relation to the transportation costs and the costs for developing extensions. At the optimum, the price and the fee (subsidy) depend on the size of the cross-group externalities. The firm balances the price and the fee (subsidy) to best internalize externalities. Extension providers are subsidized if $b > a$. Profits are increasing in cross-group externalities and the intrinsic quality of the platform. Since it becomes harder to attract consumers and extension providers, profits are decreasing in consumer transportation costs and the costs for developing extensions.

2.3 Private versus Social Incentives

We can now compare private and social incentives to allow third parties to access the platform and develop extensions for it. A private firm will provide an open platform if $\pi_O^* - \pi_C^* - F > 0$. In comparison, the socially optimal choice is to provide an open platform

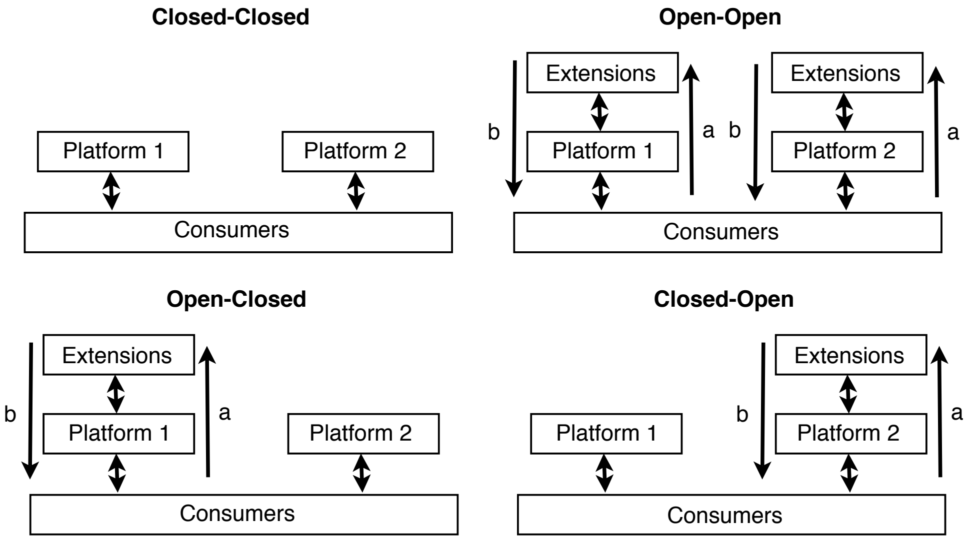

Figure 2: In stage 1, firms choose between providing an open or a closed platform. These are the possible outcomes of that choice.

if $\pi_O^* - \pi_C^* - F + (CS_O^* - CS_C^* + \Pi^*) > 0$. The difference between these two equations,

$$CS_O^* - CS_C^* + \Pi^* = \frac{(a+b)^2(12ft - (a+b)^2)v^2}{8t((a+b)^2 - 4ft)^2}, \tag{7}$$

is positive for $a, b > 0$ and $4ft - (a+b)^2 > 0$. The reason why private incentives differ from social incentives is that some of the benefits from cross-group externalities go to consumers and some to extension providers.

Proposition 1. *Private incentives to provide an open platform may be weaker than social incentives because a private firm may not be able to internalize all benefits from granting third-party producers access to the platform.*

Unless the platform can extract all benefits from cross-group externalities, the result in proposition 1 holds. Stepping out of this stylized model, the private incentives are too weak as long as $(CS_O - CS_C + \Pi) > 0$.

3 No Third-parties May Relax Competition

3.1 Setup

Now consider an extension to the above model. There are two platforms of the same intrinsic value $v > 0$. They can either be closed or open and fixed development costs, costs for opening the platform and marginal costs are zero. Consumers only buy one platform, but third-parties may provide an extension for any platform that is open.[8]

[8]Consumers singlehome and third-parties multihome, that is, they can develop for both platforms if they want to. See e.g. Armstrong (2006) and Choi (2006) for similar setups.

In stage 1, firms simultaneously decide if their platform should be open or closed. Figure 2 illustrates possible outcomes.

In stage 2, firms observe the choice made by the rival. Firms then simultaneously set the price to consumers; firms that provided open platforms also set a fee or subsidy to third-parties for the right to access the platform. Consumers and extension providers then observe prices and fees or subsidies. They form rational expectations regarding the participation of the opposite group. Consumers buy the platform yielding the highest utility and third-parties decide separately for each open platform if they should provide an extension or not.

Consumers choose between the two platforms located at the endpoints of the interval $x \in [0,1]$. The intrinsic quality of the platforms, v, is sufficiently large so that the market is completely covered.[9] In the eyes of consumers, the platforms differ only in price and the number of third-party extensions available. A consumer denoted by i receives utility $u_{i1} = (v - tx_i) + bn_{e1} - p_1$ if buying platform 1 and utility $u_{i2} = (v - t(1 - x_i)) + bn_{e2} - p_2$ if buying platform 2. The number of third-parties available at platforms 1 and 2 is given by n_{e1} and n_{e2}. Platform prices are p_1 and p_2. The transportation cost parameter, t, measures the intensity of competition between platforms.

Extension providers may develop extensions for both platforms. If both platforms are open, extension providers make the decision to develop for one platform independently from the decision to develop for the other. Thus, there is no direct competition for extension providers between firms. Extension providers must pay the fixed development cost twice if they wish to supply an extension for both platforms. Conditional on the number of consumers at each platform, an extension provider j has profits $\pi_{jk} = an_{ck} - fy_j - s_k$ from each platform $k \in \{1, 2\}$. The costs for developing extensions are sufficiently high to ensure that some developers always remain outside of the market.[10]

3.2 Stage 2: Equilibrium Prices and Fees/Subsidies

If both platforms are closed, the model reduces to the standard Hotelling model. For the consumer who is indifferent between purchasing the platform from firm 1 or firm 2, $v - tx_{in} - p_1 = v - (1-t)x_{in} - p_2$ holds. Then, demand for firm 1's platform is $n_{c1} = \frac{1}{2} + \frac{p_2 - p_1}{2t}$ and demand for firm 2's platform is $n_{c2} = 1 - n_{c1}$. The firms simultaneously set the price to consumers to maximize

$$\pi_{kCC} = p_k n_{ck}. \tag{8}$$

[9] If not, the platforms are local monopolies and the results from the monopoly model hold. The condition needed when both platforms are closed is $v > \frac{3t}{2}$. When both firms provide open platforms, the condition is $v > \frac{6ft - a^2 - 3ab}{4f}$. When one platform is closed and the other is open, the conditions are $abf(9t - 4v) > a^3b + f(6ft(3t - 2v) + b^2v) + a^2(b^2 + f(v - 3t))$ and $f(b^2(3t - v) + 6ft(2v - 3t)) > a(a^2b + 2ab^2 + b^3 - 3aft - 12bft + (a + 4b)fv)$.

[10] The assumptions needed are $f > \frac{a+b}{4}$ when the platforms are open and $f(a^2 + 4ab + b^2 + 3(a + b - 4f)t) < ab(a + b))$ when one platform is open and the other is closed.

This results in equilibrium prices of $p^*_k = t$, and profits of $\pi^*_{kCC} = \frac{t}{2}$. The second-order conditions, $-\frac{1}{t} < 0$, are satisfied. The consumer surplus is $CS^*_{CC} = \int_0^{x^*_{in}}(v - tx - p^*_1)dx + \int_{x^*_{in}}^1 (v - t(1-x) - p^*_2)dx = v - \frac{5t}{4}$. As is standard, prices and profits are decreasing in the intensity of competition between firms.

When both platforms are open the consumer who is indifferent between purchasing platform 1 and purchasing platform 2 is located at the x_i that satisfies $v + bn_{e1} - tx_i - p_1 = v + bn_{e2} - (1-t)x_i - p_2$. Demand for firm 1's platform conditional on the number of extensions at each platform is $n^{cond}_{c1} = \frac{1}{2} + \frac{bn_{e1} - bn_{e2}}{2t} + \frac{p_2 - p_1}{2t}$, and demand for firm 2's platform is $n^{cond}_{c2} = 1 - n^{cond}_{c1}$. The developer indifferent between developing and not developing an extension for platform k is located at $y_k = \frac{1}{f}(an_{ck} - s_k)$. Demand for developing extensions for platform k conditional on the number of consumers purchasing each platform is then $n^{cond}_{ek} = \frac{1}{f}(an_{ck} - s_k)$. To obtain demand as functions of prices on both sides of the market we simultaneously solve equations, $n_{c1} = n^{cond}_{c1}$, $n_{c2} = n^{cond}_{c2}$, $n_{e1} = n^{cond}_{e1}$ and $n_{e2} = n^{cond}_{e2}$. This gives

$$n_{c1} = \frac{b(s_2 - a - s_1) + f(p_2 - p_1 + t)}{2(ft - ab)}, \tag{9}$$

$$n_{c2} = \frac{b(s_1 - a - s_2) + f(p_1 - p_2 + t)}{2(ft - ab)}, \tag{10}$$

$$n_{e1} = \frac{a(b(s_1 + s_2) + f(p_2 - p_1 + t)) - a^2 b - 2fs_1 t}{2f(ft - ab)}, \text{ and} \tag{11}$$

$$n_{e2} = \frac{a(b(s_1 + s_2) + f(p_1 - p_2 + t)) - a^2 b - 2fs_2 t}{2f(ft - ab)}. \tag{12}$$

The firms simultaneously set prices, p_k, to consumers and the fees(subsidies) to extension providers, s_k, to maximize

$$\pi_{kOO} = p_k n_{ck} + s_k n_{ek}. \tag{13}$$

The equilibrium prices are $p^*_k = t - \frac{1}{4f}(a(a + 3b))$ and $s^*_k = \frac{1}{4}(a - b)$. Profits, consumer surplus and total extension provider profits at these prices are

$$\pi^*_{kOO} = \frac{t}{2} - \frac{a^2 + 6ab + b^2}{16f} \tag{14}$$

$$\begin{aligned} CS^*_{OO} &= \int_0^{x^*_{in}} (v + bn^*_{e1} - tx - p^*_1)dx + \\ &\quad \int_{x^*_{in}}^1 (v + bn^*_{e2} - t(1-x) - p^*_2)dx \\ &= v - \frac{5ft - a^2 - 4ab - b^2}{4f} \end{aligned} \tag{15}$$

$$\begin{aligned} \Pi^*_{OO} &= \int_0^{y^*_1} (an^*_{c1} - fx - s^*_1)dx + \\ &\quad \int_0^{y^*_2} (an^*_{c2} - fx - s^*_2)dx \\ &= \frac{(a+b)^2}{16f} \end{aligned} \tag{16}$$

The second-order conditions, -$\frac{f}{ft-ab} < 0$, $-\frac{2ft-ab}{f(ft-ab)} < 0$, and $\frac{8ft-a^2-6ab-b^2}{4(ab-ft)^2} > 0$ are satisfied for $4ft - (a+b)^2 > 0$. In equilibrium, firms balance the price to consumers with fees (or subsidies) to extension providers so as to best internalize cross-group externalities. Prices and profits are lower than when the platforms are closed, because both platforms have strong incentives to cut the price to consumers. These incentives are increasing in the size of the cross-group externalities. A price cut when open does not only attract more consumers but also more extension providers. The cost of providing extensions (f) affects the extent of this feedback effect. It is smaller the larger the costs of developing applications. Hence, profits (and prices) are increasing in the costs of providing extensions. Prices and profits are decreasing in the intensity of competition for consumers (decreases in t).

Consider now the case where one platform is open and one closed. Assume that firm 1 has the open platform and firm 2 has the closed platform. Conditional on the number of extensions available at platform 1, the consumer who is indifferent between platforms is located at x_{in} with x_{in} satisfying $v + bn_{e1} - tx_i - p_1 = v - (1-t)x_i - p_2$. Demand for platform 1 conditional on the number of extension providers that develop for platform 1 is $n^{cond}_{c1} = \frac{1}{2} + \frac{bn_{e1}}{2t} + \frac{p_2 - p_1}{2t}$ and demand for platform 2 is $n^{cond}_{c2} = 1 - n^{cond}_{c1}$. The developer who is indifferent between developing and not developing for platform 1 is located at $y_1 = \frac{1}{f}(an_{c1} - s_1)$. Demand for developing extensions for platform 1 conditional on the number of consumers purchasing platform 1 is then $n^{cond}_{e1} = \frac{1}{f}(an_{c1} - s_1)$. To obtain demand as a function of prices on both sides of the market, I simultaneously solve equations $n_{c1} = n_{c1}^{cond}$, $n_{c2} = n_{c2}^{cond}$ and $n_{e1} = n_{e1}^{cond}$. This gives

$$\begin{aligned} n_{c1} &= \frac{bs_1 + f(p_1 - p_2 - t)}{ab - 2ft}, && (17)\\ n_{c2} &= \frac{ab - bs_1 - f(p_1 - p_2 + t)}{ab - 2ft}, \text{ and} && (18)\\ n_{e1} &= \frac{a(p_1 - p_2 - t) + 2s_1 t}{ab - 2ft}. && (19) \end{aligned}$$

Firm 1 sets the price to consumers and the fee (or subsidy) to extension providers to maximize

$$\pi_{1OC} = p_1 n_{c1} + s_1 n_{e1}. \quad (20)$$

Firm 2 simultaneously sets the price to consumers to maximize

$$\pi_{2OC} = p_2 n_{c2}. \quad (21)$$

Equilibrium prices are

$$\begin{aligned} p_1^* &= \frac{(4ft - a(a+b))(3ft - ab)}{f(12ft - a^2 - 4ab - b^2)}, && (22)\\ s_1^* &= \frac{(a-b)(3ft - ab)}{12ft - a^2 - 4ab - b^2}, \text{ and} && (23)\\ p_2^* &= \frac{(6ft - (a+b)^2)(2ft - ab)}{f(12ft - a^2 - 4ab - b^2)}. && (24) \end{aligned}$$

Platform profits, consumer surplus and extension provider profits are

$$\begin{aligned} \pi_{1OC}^* &= \frac{(8ft - (a+b)^2)(ab - 3ft)^2}{f(a^2 + 4ab + b^2 - 12ft)^2}, && (25)\\ \pi_{2OC}^* &= \frac{((a+b)^2 - 6ft)^2(2ft - ab)}{f(a^2 + 4ab + b^2 - 12ft)^2}, && (26)\\ CS_{OC}^* &= \int_0^{x_{in}^*} (v + bn_{e1OC}^* - tx - p_{1OC}^*)dx + \\ &\quad \int_{x_{in}^*}^1 (v - t(1-x) - p_{2OC}^*)dx \\ &= \frac{2(ab - 3ft)(((a+b)^2 - 5ft)(ab - 3ft) + f(a^2 + 4ab + b^2 - 12ft)v)}{f(a^2 + 4ab + b^2 - 12ft)^2} + \\ &\quad \frac{((a+b)^2 - 6ft)(((a+b)^2 - 6ft)(2ab - 5ft) + 2f(a^2 + 4ab + b^2 - 12ft)v)}{2f(a^2 + 4ab + b^2 - 12ft)^2}, && (27)\\ \Pi_{OC}^* &= \int_0^{y_{iOC}^*} (an_{c1OC}^* - fy - s_{1OC}^*)dy + \int_0^{y_{iOC}^*} (an_{c1OC}^* - fy - s_{1OC}^*)dy \\ &= \frac{(a+b)^2(ab - 3ft)^2}{2f(a^2 + 4ab + b^2 - 12ft)^2}. && (28) \end{aligned}$$

The second-order conditions -$\frac{2f}{2ft-ab} < 0$, $-\frac{4t}{2ft-ab} < 0$ and $\frac{8ft-(a+b)^2}{(ab-2ft)^2} > 0$ are satisfied

		Firm 2	
		C	O
Firm 1	C	$(\pi^*_{1CC}, \pi^*_{2CC})$	$(\pi^*_{1CO},\pi^*_{2CO})$
	O	$(\pi^*_{1OC},\pi^*_{2OC})$	$(\pi^*_{1OO},\pi^*_{2OO})$

Figure 3: The simultaneous game played by private firms before they set prices and fees.

for $4ft - (a+b)^2 > 0$. By reversing the identities of the platforms, we can obtain profits under the outcome Closed-Open. These profits are $\pi^*_{1CO} = \pi^*_{2OC}$ and $\pi^*_{2CO} = \pi^*_{1OC}$. Application developers are subsidized if $b > a$. The size of the cross-group externalities and the costs of developing applications can either increase or decrease the profits. The reason is that while cross-group externalities benefit the platform, they also lead to intensified competition for consumers (more on this below).

3.3 Stage 1: Private Versus Social Incentives

Let us now compare private and social incentives to provide an open platform. Start with social incentives. Which of the four possible combinations of open and closed platforms would maximize social welfare? Suppose that we measure social welfare as the unweighted sum of consumer surplus, firm profits and third-party producer profits. Then, it is best for society as a whole to have both platforms open if

$$CS^*_{OO} + \pi^*_{1OO} + \pi^*_{2OO} + \Pi^*_{1OO} > CS^*_{CC} + \pi^*_{1CC} + \pi^*_{2CC}, \quad (29)$$

$$CS^*_{OO} + \pi^*_{1OO} + \pi^*_{2OO} + \Pi^*_{1OO} > CS^*_{OC} + \pi^*_{1OC} + \pi^*_{2OC} + \Pi^*_{OC}, \text{ and} \quad (30)$$

$$CS^*_{OO} + \pi^*_{1OO} + \pi^*_{2OO} + \Pi^*_{1OO} > CS^*_{CO} + \pi^*_{1CO} + \pi^*_{2CO} + \Pi^*_{CO}. \quad (31)$$

The first condition always holds since the difference between the left-hand and right-hand side is $\frac{1}{f}((a+b)^2) > 0$. The second and third conditions are equivalent in this model. It is possible to show that they hold for ft sufficiently large.[11] Hence, for sufficiently large ft, it is socially optimal to have both platforms open.

If the firms privately choose between open and closed platforms, they play the simultaneous move game in figure 3. Each firm will have a dominant strategy to provide an open platform if

$$\pi^*_{1OC} > \pi^*_{1CC}, \quad (32)$$

$$\pi^*_{2CO} > \pi^*_{2CC}, \quad (33)$$

$$\pi^*_{1OO} > \pi^*_{1CO}, \text{ and} \quad (34)$$

$$\pi^*_{2OO} > \pi^*_{2OC}. \quad (35)$$

The first two and the second two conditions are equivalent. The first two conditions hold

[11] The difference between the left-hand and right-hand side can be simplified to $4(17a^4+72a^3b+106a^2b^2+72ab^3+17b^4)ft < 3(a+b)^2(a^4+8a^3b+10a^2b^2+8ab^3+b^4+72f^2t^2)$, which holds for sufficiently large ft.

for $2a^2b^2 + (a^2 - 6ab + b^2)ft > 0$, which is positive for large ft only if $a^2 - 6ab + b^2 > 0$ or, equivalently, if $(a - b)^2 - 4ab > 0$. Hence, for large ft and sufficiently small difference in cross group externalities, so that $(a - b)^2 - 4ab < 0$, firms would not have any incentives to provide open platforms even if it were socially desirable. The reason is that opening the platform makes the rival more aggressive in pricing.

Proposition 2. *There exist cases where competing platforms exclude third-party providers in a sub-game perfect equilibrium. This exclusion is socially inefficient, both because third-party providers are excluded and because it relaxes the competition for consumers.*

To see that competition is intensified, consider the best response functions of the firms. The best response functions for price for firm 1 when its platform is closed are $p_1(p_2)_{CC} = \frac{t+p_2}{2}$, and $p_1(p_2, s_2)_{CO} = \frac{t+p_2}{2} - \frac{b(a-s_2)}{2f}$. When firm 1 provides an open platform, the best response functions are $p_1(s_1, p_2)_{OC} = \frac{t+p_2}{2} - \frac{(a+b)s_1}{2f}$, and $p_1(s_1, p_2, s_2)_{OO} = \frac{t+p_2}{2} - \frac{(a+b)s_1}{2f} - \frac{b(a-s_2)}{2f}$. Studying these, we can see that because $\frac{b(a-s_2)}{2f} > 0$ in equilibrium, firm 1 has incentives to price more aggressively if firm 2 provides an open platform.

4 Conclusions

Do private firms allow third-parties to access their platform and develop extensions for their product when this is socially desirable? In this paper I proposed two reasons for why this may not be true. First, a private firm may not be able to internalize all benefits from cross-group externalities arising with third-party extensions. Second, firms may have strategic incentives to shut out producers of third-party extensions as a device for relaxing competition for consumers.

My analysis suggests that private incentives to allow third-parties access to platforms may be insufficient. Hence, it supports the argument that policy should be directed towards supporting open platforms that allow third-parties to access the platform and develop extensions for it.

One could think of numerous extensions to this simple framework. First, it was assumed in the duopoly model that the market was completely covered on the consumer side. This implies that price cuts for consumers or changes in quality do not attract any new customers. Maintaining the assumption of a covered market thus biases the results in favor of closed platforms. However, the assumption does not change the fact that competition between open platforms is more intense than competition between closed platforms. Hence, the trade-off between intensified competition and a higher quality platform still remains, even though platforms might have stronger incentives to provide open platforms. From a welfare perspective, a covered market implies that potential changes in deadweight loss are not accounted for. If the market were uncovered, intensified competition due to open platforms would be likely to reduce dead weight losses. This would further strengthen the result that private duopolists may have insufficient incentives to provide open platforms, if closed platforms are provided in order to relax competition.

Second, it was assumed in both the monopoly and the duopoly model that the firms can only set a fixed price to consumers and a fixed fee (or subsidy) to extension providers. This price structure was chosen for simplicity, but different price structures can easily be imagined. One potential extension might be to allow firms to implement perfect price discrimination and extract all surplus from consumers and extension providers. In this case, the result that private incentives to provide an open platform may be insufficient may no longer hold in the monopoly setup as both private and social incentives are aligned. Another potential extension could be to consider two-part tariffs. This would be a great avenue for further research as very little is known about the effects of two-part tariffs in two-sided markets.

APPENDIX

A. Monopoly Setting with Platform Located at $x = \frac{1}{2}$

Suppose that the platform is located at $x = \frac{1}{2}$. The following expressions then change. When the platform is closed, demand is $n_c(p) = \frac{1}{t}2(v - p)$ and the consumer surplus is $CS_C = \frac{1}{4t}v^2$. When the platform is open, demand on each side of the market as a function of both prices are $n_c(p, s) = \frac{2}{ft-2ab}(f(v - p) - bs)$ and $n_e(p, s) = \frac{1}{ft-2ab}(2a(v - p) - st)$, respectively. The consumer surplus is $CS_O = \frac{v^2 f^2 t}{((a+b)^2-2ft)^2}$. Equation 7 then becomes

$$CS_O^* - CS_C^* + \Pi^* = \frac{(a + b)^2(6ft - (a + b)^2)v^2}{4t((a + b)^2 - 2ft)^2}, \tag{36}$$

which is positive. Hence, proposition 1 still holds if the platform is located at $x = \frac{1}{2}$ instead of at $x = 0$.

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ESSAYS ON PLATFORMS

BUSINESS STRATEGIES, REGULATION AND POLICY IN TELECOMMUNICATIONS, MEDIA AND TECHNOLOGY INDUSTRIES

The growth of the information economy has been stellar in the last decade. General-purpose technologies such as the computer and the Internet have promoted productivity growth in a large number of industries. The effect on telecommunications, media and technology industries has been particularly strong. These industries include mobile telecommunications, printing and publishing, broadcasting, software, hardware and Internet services. There have been large structural changes, which have led to new questions on business strategies, regulation and policy. This thesis focuses on four such questions and answers them by extending the theoretical literature on platforms. The questions (with short answers) are:

(i) Do we need to regulate how Internet service providers discriminate between content providers? (Yes.)

(ii) What are the welfare effects of allowing consumers to pay to remove advertisements from advertisement-supported products? (Ambiguous, but those watching ads are worse off.)

(iii) Why are some markets characterized by open platforms, extendable by third parties, and some by closed platforms, which are not extendable? (It is a trade-off between intensified competition for consumers and benefits from third parties)

(iv) Do private platform providers allow third parties to access their platform when it is socially desirable? (No.)

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