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. Platforms sell Internet access services to consumers and may set fees to content - and application providers on the Internet. When access is monopolized, for reasonable parameter ranges, net neutrality regulation (requiring zero fees to content providers) increases the total industry surplus as compared to the fully private optimum at which the monopoly platform imposes positive fees on content providers. However, there are also parameter ranges for which total industry surplus is reduced. Imposing net neutrality in duopoly with multi-homing content providers and single-homing consumers increases the total surplus as compared to duopoly competition with positive fees to content providers.

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

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

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1. <u>Introduction</u>

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. The typical contract of an Internet service provider (ISP) with a customer gives access to the customer to the whole Internet through a physical or virtual pipe of a certain bandwidth. Similarly, an ISP buys from an Internet backbone network access to the whole Internet through a physical or virtual pipe of a certain bandwidth in a service called "transit." "Transit" delivers access to the buyer to the *whole* Internet and therefore the buyer/ISP does not need to have any contractual relationship with any other ISP except its backbone provider.[1]

The price a customer pays to an ISP for Internet access depends crucially on the availability of competing ISPs for this customer. Customers that are not locationally constrained and can connect to the Internet at many locations can negotiate very small connection charges. Content/applications providers are typically not locationally constrained and have negotiated very small Internet access charges. In contrast, residential customers typically face a local monopoly or duopoly and have much higher charges.

As search services, video services and digital distribution of content over the

[1] ISPs can also accept payment in kind, that is, barter, called 'peering,' Peering is a restricted service whereby two interconnecting networks agree not pay each other for carrying the traffic exchanged between them as long as the traffic originates and terminates in the two networks. For a more detailed

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." [2] Naturally, no one is using the Internet for free, since both sides of an Internet transfer pay.[3] 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.[4] 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.[5] The way the Internet has operated so far is a radical departure from the operating principles of the traditional digital electronic networks predating it, such as Compuserve, Prodigy, AOL, AT&T Mail, MCI Mail and others. These older electronic networks were centralized with

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description, see Economides (2005, 2007).

[2] 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!

[3] See Economides (2005, 2007).

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

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

very little functionality allowed at the edge of the network.

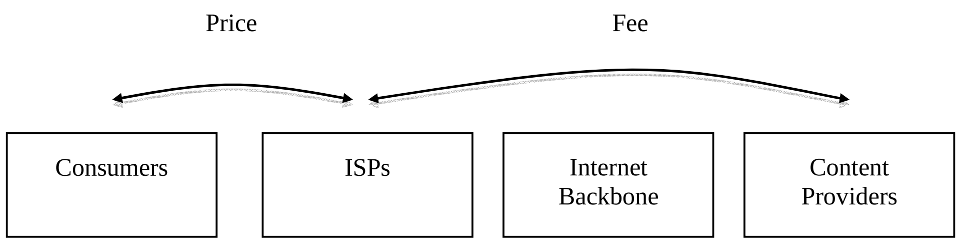
From an economics point of view, the departure from net neutrality regulation will have six consequences. First, it will introduce the possibility of *two-sided pricing* on the Internet where a transmission company controlling some part of the Internet (here *last mile access*) will charge a fee to content- or application firms "on the other side" of the network which typically did not have a contractual relationship with it. This is over and above the traditional *one-sided* payment to its ISP for "transit service" whereby a content or applications provider connects to the Internet. Second, it will introduce the possibility for 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.[6] 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

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

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,[7] 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 thus only concentrate on the issue of one-sided versus two-sided pricing (which we think should play a larger role in the debate) and ignore other (admittedly important) issues such as exclusion of content providers, quality of service variations, dynamic investment incentives and price discrimination. We explicitly model the Internet 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 on the number of broadband consumers as well as on 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 to content providers over and above charges for sending and receiving traffic from the Internet backbone. Figure 1 shows the conceptual structure of the Internet connecting consumers and content providers.

[7] 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."



<u>Figure 1</u>: **We take the Internet Backbone competitive and consider the price for Internet access that consumers pay and possible direct fees imposed on content providers by ISPs. These fees are possible if net neutrality is abolished and an ISP can 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 some parameter ranges when the monopolist would like to charge content providers, an increase in such a fee above zero decreases the total surplus. However, there also exist parameter values for which this result is overturned. Further, we show that in a duopoly setting with multi-homing content providers and single-homing consumers, 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.[8] Focusing on congestion, Cheng, Bandyopadhyay and Guo (2008) model two content providers who can avoid congestion by paying ISPs for preferential access.[9] 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 (2008) 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. Investing in improving capacity implies that the network operator can charge less for prioritized delivery, so incentives to expand capacity can be lower without net neutrality regulation. 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

[8] 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.
[9] See also Jamison and Hauge (2008).

encourage some investment by content providers. [10]

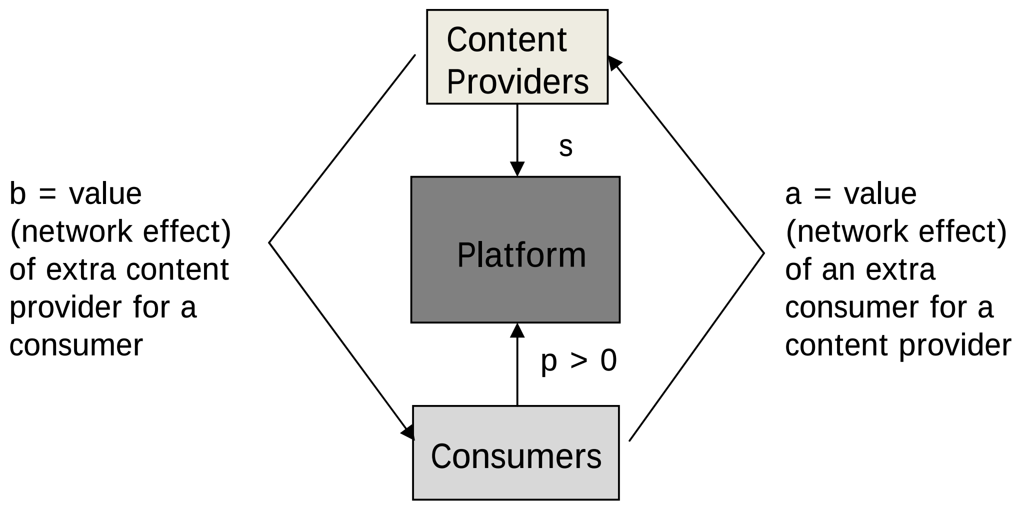
In contrast to the above literature, we focus on the issue of two-sided pricing made possible by the abolishment of net neutrality regulation. Hence, our paper is closely related to the literature on two-sided markets (e.g. Armstrong (2006), Caillaud and Jullien (2003), Hagiu (2006), Rochet and Tirole (2003, 2006) and Nocke, Peitz and Stahl (2007)). In particular, we build on the approach in Armstrong (2006) by extending it to study net neutrality regulation, and by studying optimal regulation of one price in a two-sided market while the platforms are allowed to optimally set the other price in response. 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

[10] 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



<u>Figure 2</u>: **Interaction of consumers with content providers and vice versa through the 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. [11] 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).[12] 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

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cost of the application and hence, also its price.

[11] One could alternatively view our setup also as only considering consumer and content provider use of a high speed dedicated "last mile laser" offered to content providers needing a high level of quality of service to ensure that, for example, HD video transmissions work well.

[12] 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.

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."[13] 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,[14] b is the marginal value that a 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.

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.[15] The marginal costs for serving advertisements to consumers are

[13] Assume that the market is not covered and demand is differentiable.
[14] 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 with Internet access.
[15] 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.

taken to be zero.[16] 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[17]

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

Net neutrality regulation equals the case where s is zero. As discussed earlier, the traditional fees paid for transit service by content/applications providers are small, and here take them to be zero at the *status quo* net neutrality regime.[18] 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

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[16] See Appendix C for a discussion on how positive marginal costs on the content provider side affect our results.
[17] 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.
[18] In any case, we can interpret the fee *s* as the increment above the traditional transit fee.

(4), which is $n_c(p,s) = \frac{f(v-p)-bs}{ft-ab}$ and $n_{cp}(p,s) = \frac{a(v-p)-ts}{ft-ab}$.[19]

Given this setup, we now study the monopoly platform optimum, the optimum with net neutrality regulation and the social optimum. Then, we consider the welfare implications of imposing net neutrality regulation.

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 s to content providers. The platform faces the problem of choosing p and s to maximize

$$\Pi(p,s) = (p-c)n_c(p,s) + sn_{cp}(p,s)\,. \tag{5}$$

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

$$p(s) = \frac{f(v+c)-(a+b)s}{2f}\,, \tag{6}$$

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

$$s(p) = \frac{av+bc-(a+b)p}{2t}\,. \tag{7}$$

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:[20]

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

[20] The second order conditions are satisfied for $4ft-(a+b)^2 > 0$.

$$p^M = \frac{(2ft - ab)(v+c) - b^2c - a^2v}{4ft - (a+b)^2} \tag{8}$$

and

$$s^M = \frac{(a-b)f(v-c)}{4ft-(a+b)^2} \tag{9}$$

Superscript *M* indicates the fully private optimum where both p and s are chosen by the monopoly platform. The participation levels are $n_c^M = \frac{2f(v-c)}{4ft-(a+b)^2}$ and $n_{cp}^M = \frac{(a+b)(v-c)}{4ft-(a+b)^2}$, and the profits of the monopoly platform are $\Pi^M = \frac{f(v-c)^2}{4ft-(a+b)^2}$.[21, 22]

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 monopoly platform service provider sets a positive fee to content providers for accessing users ($s^M > 0$) only if $\frac{a}{b} > 1$. 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 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.

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[21] 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.

[22] Note that 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).

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 ($s^M > 0$), we assume that a content provider values an additional consumer more than a consumer values an additional content provider:

Assumption 1: *A content provider values an additional consumer more than a consumer values an additional content provider:* $\frac{a}{b} > 1$.

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. 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, $\frac{a}{b} < 1$. 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.[23] 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.*,

[23] See also Economides and Katsamakas (2006a, b) for a deeper discussion of this issue and a contrast with practices in open source operating systems. 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 (2009) and Rochet and Tirole (2003).

$\frac{a}{b} < 1$.[24]

In summary, we have shown that an unconstrained profit-maximizing monopoly platform charges a positive fee to content providers if and only if content providers value additional consumers more highly than consumers value additional content providers. For an interior maximum, we also need to impose the following technical assumption ensuring sufficient differentiation among consumers and content providers.

Assumption 2: $ft-(a+b)^2>0$, that is, jointly consumers and content providers are sufficiently differentiated.

2.5 Monopoly Platform Optimum 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 $\Pi^{NN}=(p-c)n_c$, which gives the equilibrium price $p^{NN}=\frac{v+c}{2}$. The second-order condition $-\frac{2f}{ft-ab}<0$ is satisfied when $ft-ab>0$. Equilibrium participation levels are $n_c^{NN}=\frac{f(v-c)}{2(ft-ab)}$ and $n_{cp}^{NN}=\frac{a(v-c)}{2(ft-ab)}$.[25] The platform's profits are $\Pi^{NN}=\frac{f(v-c)^2}{4(ft-ab)}$.

2.6 Social Optimum with a Monopoly Platform

We now solve for prices p and s that maximize the total surplus defined as $TS(p,s)=\Pi(p,s)+CS_c(p,s)+\Pi_{cp}(p,s)$, where $\Pi(p,s)$ are platform profits,

[24] In this case, we place the consumers at the top of Figure 2 and the credit card issuing banks at the bottom.

[25] 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.

$$CS_c(p,s) = \int_0^{n_c(p,s)} (v + bn_{cp}(p,s) - tx - p)dx \qquad (10)$$

is consumer surplus and

$$\Pi_{cp} = \int_0^{n_{cp}(p,s)} (an_c(p,s) - fy - s)dy, \qquad (11)$$

is the sum of the content providers' profits. Maximizing the total surplus,[26] a planner chooses $p^* = \frac{ftc - b(a+b)c - a(a+b)v}{ft - (a+b)^2} < c$ and $s^* = -\frac{bf(v-c)}{ft - (a+b)^2} < 0$. This results in maximized total surplus $TS(p^*, s^*) = \frac{f(v-c)^2}{2(ft - (a+b)^2)}$.

Note that in our case, with $\frac{a}{b} > 1$, clearly $s^* < 0 < s^M$. But even in industries where $\frac{a}{b} < 1$ 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 $ft > \frac{a(a+b)^2}{(a+3b)}$, that is, when there is a sufficiently high differentiation among consumers and content firms. We can also note that constraining the price to consumers to equal marginal cost, gives $s^{**} = -\frac{b(a^2 + ft)(v-c)}{t(ft - 2ab - b^2)} < 0$ since $ft > (a+b)^2$.

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[26] 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.

The maximized surplus is $TS(c,s^{**})=\frac{(ft+a^2)(c-v)^2}{2t(ft-2ab-b^2)}$.[27] Similarly, if the content provider price is constrained to marginal cost (i.e. zero), the socially optimal price to consumers is below marginal cost since choosing p to maximize $TS(p,0)$ gives

$p^{**}=\frac{(ft-ab)c-a^2v-abv}{ft-2ab-a^2}<c$. The maximized surplus is

$TS(p^{**},0)=\frac{ft(c-v)^2}{2(ft-a(a+ab))}$.[28]

Hence, to summarize, it is clear that:

- A total surplus maximizing planner/regulator in the two-sided market with network effects chooses below-cost pricing in both markets.
- 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.
- 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.[29]

Due to the network effects arising from the complementarity of the content-

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[27] The sufficient condition for a maximum is $-\frac{t(ft-2ab-b^2)}{(ft-ab)^2}<0$.

[28] The sufficient condition for a maximum is $-\frac{f(ft-2ab-a^2)}{(ft-ab)^2}<0$.

[29] 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 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 $\frac{TS(p^*,s^*)-TS(p^{NN},0)}{TS(p^*,s^*)}=\frac{a^4-2ab^3+ft(3b^2+ft)+a^2(b^2+2ft)}{4(ft-ab)^2}$.

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

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(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 to a small positive value is

$$\frac{d\Pi\Big|_{\frac{\partial\Pi}{\partial p}=0}}{ds}\Big|_{s=0} = \frac{d\Pi(p(s),s)}{ds}\Big|_{s=0} = \frac{(a-b)(v-c)}{2(ft-ab)}, \qquad (12)$$

which is positive for $\frac{a}{b} > 1$. 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

$$\frac{dTS\Big|_{\frac{\partial\Pi}{\partial p}=0}}{ds}\Big|_{s=0} = \frac{dTS(p(s),s)}{ds}\Big|_{s=0} = \frac{(v-c)(a(a^2-ab+2b^2)+(a-3b)\,ft)}{4(ft-ab)^2}, \qquad (13)$$

which is negative provided that $a < 3b$ and ft is sufficiently large. We also require concavity of $TS(p(s),s)$, for which it is sufficient that $a \le 2b$.[30] Thus, for $\frac{a}{b} \in (1,2]$ 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 1</u>**: For $\frac{a}{b} \in (1,2]$ and ft sufficiently large:*

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[30] 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 $a \le 2b$ and ft sufficiently large.

(i) 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.*

(ii)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, if $\frac{a}{b} \in (1, 2]$ and ft sufficiently large. 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

$$s^{***} = \frac{f(v-c)(a(a^2-ab+2b^2)+(a-3b)\,ft)}{(a^2-6ab-3b^2)\,ft+4f^2t^2-a(a-2b)(a+b)^2} \qquad (14)$$

and the corresponding monopolist's subscription price

$$p^{***} = \frac{a^2(cft+b^2(2c+v))+a(2bft(2c+v)-2cb^3)-a^4v-\ ft(3b^2c-2\,ft(c+v))}{(a^2-6ab-3b^2)\,ft+4f^2t^2-a(a-2b)(a+b)^2}. \qquad (15)$$

The fee s^{***} to content providers is negative provided that $\frac{a}{b} < 3$ and ft is sufficiently large.[31] Given that the s^{***} is negative, the platform profits from consumers cover the subsidy to content providers if:

$$(\mathrm{ft})^2(3a^2-10ab-9b^2+4\,ft)-a(a+b)(a(a+b)(a^2-3ab+4b^2)+(a-3b)(a+4b)\,ft)>0, \qquad (16)$$

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

which is true for a sufficiently large *ft*.[32] Thus, the platform's profits are positive even when, following the regulator's orders, the platform provides subsidy $-s^{***}$ to the other side of the market.[33]

Proposition 2: *For* $\frac{a}{b} \in (1,3)$ *and ft sufficiently large, 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. We then obtain the following proposition:

Proposition 3: *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* $\frac{a}{b} \in (1,5)$.

Proof. *See appendix A.*

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

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

[33] We have also considered the possibility that the regulator can set the price to users but allows the platform to set a fee to content providers. In that case, the regulator maximizes $TS(\hat{p}, s(\hat{p}))$ by choosing $\hat{p}$. This leads the regulator to choose a below-cost user price
$\hat{p} - c = -\frac{(a+b)(2a^2b + 2bft - a(b^2 + 3ft))(c-v)}{(2a-b)b(a+b)^2 + (-3a^2 - 6ab + b^2)\,ft + 4f^2t^2} < 0$ and, in response, the platform chooses an above-cost content-provider fee $s(\hat{p}) = \frac{f(a^2b + b^3 - 2aft)(c-v)}{(2a-b)b(a+b)^2 + (-3a^2 - 6ab + b^2)\,ft + 4f^2t^2} > 0$.

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 Summary of Results for Platform Monopolist

We have showed that for some 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. The sum of these changes determines the impact on total welfare. It may be positive or negative, but for large *ft* and when ($\frac{a}{b} \in (1,5)$), 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_{cpk}^{e} 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

$$v + bn_{cp1}^{e} - tx_i - p_1 = v + bn_{cp2}^{e} - t(1 - x_i) - p_2 . \tag{17}$$

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

$n_{c1} = \frac{1}{2} - \frac{b(n_{cp2}^{e} - n_{cp1}^{e}) - (p_2 - p_1)}{2t}$ and $n_{c2} = 1 - n_{c1}$.

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_{ck}^{e}, if the content provider buys access from platform k, $k \in \{1, 2\}$. The total revenue for each content provider is an_{ck}^{e}.

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

$$\pi_{jk} = an_{ck}^{e} - s_k - fy_j \,. \qquad (18)$$

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 $n_{cpk} = \frac{an_{ck}^{e} - s_k}{f}$, $k \in \{1,2\}$. Since consumers single-home, content providers can only reach the consumers of each platform by buying access from that platform.[34]

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

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

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

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

Given this setup, we first consider the unrestricted duopoly equilibrium, then the duopoly equilibrium under net neutrality regulation and finally we study the welfare implications of imposing net neutrality regulation.

[34] 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).

3.4 Unrestricted Duopoly Equilibrium

When the duopoly platforms are free to set prices to both consumers and content providers, platform k maximizes $\Pi_k(p_1, p_2, s_1, s_2) = (p_k - c)n_{ck} + s_k n_{cpk}$, with $k = 1, 2$, resulting in equilibrium prices

$p_1^D = p_2^D = t + c - \frac{a^2 + 3ab}{4f}$ and $s_1^D = s_2^D = \frac{a-b}{4}$.[35,36] The firms split the market on the consumer side and the profits are $\Pi_1^D = \Pi_2^D = \frac{4ft - (a+b)^2 + 4(ft - ab)}{16f}$.

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 $\Pi_1 = (p_1 - c)n_{c1}$ and $\Pi_2 = (p_2 - c)n_{c2}$ with respect to p_1 and p_2, respectively, resulting in equilibrium prices of

$p_1^{DNN} = p_2^{DNN} = t + c - \frac{ab}{f}$.[37] The firms split the market equally on the consumer side and their profits are $\Pi_1^{DNN} = \Pi_2^{DNN} = \frac{1}{2}(t - \frac{ab}{f})$.

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[35] The second-order conditions are $-\frac{f}{ft - ab} < 0$, $-\frac{(2ft - ab)}{f(ft - ab)} < 0$ and $\frac{(4ft - (a+b)^2) + 4(ft - ab)}{4(ab - ft)^2} > 0$ and are satisfied since we have assumed that $4ft - (a+b)^2 > 0$.

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

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

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

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

$$\left.\frac{d\Pi_1\Big|_{\frac{\partial\Pi_1}{\partial p_1}=\frac{\partial\Pi_2}{\partial p_2}=0}}{ds_1}\right|_{s_1=s_2=0} = \left.\frac{d\Pi_2\Big|_{\frac{\partial\Pi_1}{\partial p_1}=\frac{\partial\Pi_2}{\partial p_2}=0}}{ds_2}\right|_{s_1=s_2=0} = \frac{a-b}{3f} > 0 \tag{19}$$

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

$$CS = \int_0^{n_{c1}} (v + bn_{cp1} - tx - p_1)dx + \int_{n_{c1}}^{1} (v + bn_{cp2} - t(1-x) - p_2)dx, \tag{20}$$

the sum of platform profits,

$$\Pi_1 = (p_1 - c)n_{c1} + s_1 n_{cp1}, \quad \Pi_2 = (p_2 - c)n_{c2} + s_2 n_{cp2} \tag{21}$$

and total content provider profits

$$\Pi_{cp} = \int_0^{n_{cp1}} (an_{c1} - s_1 - fy)dy + \int_0^{n_{cp2}} (an_{c2} - s_2 - fy)dy. \tag{22}$$

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[38]

$$\frac{dTS\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{ds_1}\Bigg|_{s_1=s_2=0} = \frac{dTS\Big|_{\frac{\partial \Pi_1}{\partial p_1}=\frac{\partial \Pi_2}{\partial p_2}=0}}{\partial s_2}\Bigg|_{s_1=s_2=0} = -\frac{b}{2f} < 0. \tag{23}$$

Hence, as in monopoly, social and private incentives go in opposite directions in duopoly, if $\frac{a}{b} > 1$. 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 4:

(i) 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.

(*ii) 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

[38] 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 $a + b - 2f > 0$.

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 5: *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

$$\frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1} = \frac{\partial \Pi_2}{\partial p_2} = 0}}{ds_1}\Bigg|_{s_1 = 0} = \frac{(a-b)}{3f} - \frac{(a-b)^2 s_2}{9f(ft - ab)} \qquad (24)$$

and therefore,

$$\frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1} = \frac{\partial \Pi_2}{\partial p_2} = 0}}{ds_1}\Bigg|_{s_1 = 0} - \frac{d\Pi_1\Big|_{\frac{\partial \Pi_1}{\partial p_1} = \frac{\partial \Pi_2}{\partial p_2} = 0}}{ds_1}\Bigg|_{s_1 = s_2 = 0} = -\frac{(a-b)^2 s_2}{9f(ft - ab)} < 0 \qquad (25)$$

Thus, for $\frac{a}{b} > 1$, 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.

<u>Proposition 6</u>*:* *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. We obtain the following proposition.

<u>Proposition 7</u>: *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.*

Proof. See appendix A.

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.

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.[39] Given subscription fees s_1 and s_2, the non-cooperative equilibrium subscription prices are

$$p_1(s_1, s_2) = \frac{b(s_2 - s_1) - a(3b + 2s_1 + s_2)}{3f} + t + c \,, \qquad \text{and} \qquad (26)$$

$$p_2(s_1, s_2) = \frac{b(s_1 - s_2) - a(3b + 2s_2 + s_1)}{3f} + t + c \,. \qquad (27)$$

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.

Proposition 8: *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.*

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

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.[40] In platform duopoly, we find that for $\frac{a}{b} > 1$, 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 to 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 for 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 some parameter values, society is better off in terms of total surplus at net neutrality rather than either the monopolist's or

[40] 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).

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 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.[41]

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

APPENDIX

A. Proof of Propositions

Proof of Proposition 3. 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

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

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

while the difference in equilibrium participation levels is

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

$$\Delta n_{cp} = n_{cp}^M - n_{cp}^{NN} = (v-c)\left(\frac{a+b}{4ft-(a+b)^2} - \frac{a}{2(ft-ab)}\right) < 0.$$ [42]

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

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

Total consumer surplus and content provider profits under private optimum are

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

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[42] 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.

and under net neutrality regulation

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

The change in consumer surplus when net neutrality regulation is removed is then[43]

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

and the change in content provider profits

$$\Delta \Pi_{cp} = \Pi_{cp}^M - \Pi_{cp}^{NN} = \frac{1}{8} f(v-c)^2 (\frac{4(a+b)^2}{(4ft-(a+b)^2)^2} - \frac{a^2}{(ft-ab)^2}) < 0.$$ [44]

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

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

and under net neutrality regulation

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

The change in total surplus is then

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

which is negative provided that $\frac{a}{b} < 5$ and ft is sufficiently large.[45] Thus, removing

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[43] 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 $4ft-(a+b)^2 > 0$.

[44] 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.

net neutrality regulation decreases social welfare for this parameter range, while social welfare is increased otherwise.

Proof of Proposition 7. 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

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

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

and the difference in content provider participation is

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

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

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

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

and

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

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

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

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[45] 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 $a < 5b$.

B. Duopoly Model with Demand Expansion Effects (Hinterlands) on the Consumer Side of the Market

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

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

$$s_1^D = s_2^D = \frac{(a-b)f(4ab - 3ft)(2c + (2d-1)t - 2v)}{8ab(a+b)^2 - 2(3a^2 + 20ab + 3b^2)ft + 20f^2t^2}.$$ [46]

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

$$p_1^{DNN} = p_2^{DNN} = \frac{ft(-3c - t + 2dt - 2v) + 2ab(2c + t - 2dt + 2v)}{8ab - 5ft}.$$ [47]

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

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

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[46] 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.

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

$$\Delta CS = CS^{D} - CS^{DNN} > 0,$$
$$\Delta \Pi_1 = \Pi_1^{D} - \Pi_1^{DNN} = \Delta \Pi_2 = \Pi_2^{D} - \Pi_2^{DNN} > 0\,,$$
$$\Delta \Pi_{cp} = \Pi_{cp}^{D} - \Pi_{cp}^{DNN} < 0\,.$$
$$\Delta TS = TS^{D} - TS^{DNN} < 0\,.$$[48]

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

[48] 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

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

C. Positive 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 holds for $f(a-b)(v-c)+(2ft-a^2-ab)k>0$ and k sufficiently small.
- Proposition 2 holds for small k.
- Proposition 3 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 4 holds for $b-2k>0$ (if k is sufficiently small).
- Proposition 5 holds for $b-2k>0$ (if k is sufficiently small).
- Proposition 6 holds.
- Proposition 7 holds for $6k<a+3b$ (if k is sufficiently small).
- Proposition 8 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.

D. 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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