

Regulation of Internet Access

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Abstract

We analyze the welfare implication of regulating the price of last-mile access to consumers provided by local Internet service providers (ISPs). We consider a new two-sided market model that highlights the vertical relationship between two platforms, a local ISP and a large content provider called a Content Network Platform (CNP) that plays the role of platform in the *content* markets. The welfare implication of regulating the Internet access depends on which of the two platforms holds a dominant factor in creating consumer demand for the Internet. If the ISP's Internet subscription price is the dominant factor, regulation alleviates inefficiencies due to the ISP's market power and, thus, is likely to improve welfare.

Keywords: Internet, Net Neutrality, Access Regulation, Two-Sided Markets.

JEL codes: L51, K23, D43, H00

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1 Introduction

Net neutrality is a general principle that advocates open access to the Internet.¹ Although there are many aspects of net neutrality rules, the focus of current debates is whether ISPs should be allowed to charge content providers (CPs) to reach consumers in their network. The FCC's new net neutrality rules proposed in May 2014 allow ISPs to charge CPs for fast lanes.² In contrast, the European Parliament voted in April 2014 to restrict the ability of ISPs to charge for fast lanes.³

Without neutrality rules, paid prioritization of fast lane traffic will become a standard means of data discrimination. On the Internet, content that does not arrive quickly to consumers' Internet devices cannot survive since consumers would simply click away from such content. Thus, all CPs who can afford the payment will end-up paying for the fast lane, whereas those who cannot will perish in the long run. Thus, abolishing net neutrality will, in essence, increase the online operating costs of all remaining CPs.

With this long term view in mind, we model the absence of net neutrality as the ability of local ISPs to optimally charge CPs for last-mile access to consumers, which is similar in nature to the 2013 agreement between Google and the French ISP Orange.⁴ We examine the welfare implications of a policy that imposes an upper bound, currently at zero, for the price of this monopoly input, access fee, provided by local ISPs.

The unique feature of the Internet content markets is that there are a few *large* CPs (e.g., Google), which we call Content Network Platforms (CNPs), whose main function is to mediate smaller CPs and consumers. The CNPs differ significantly from large CPs with market power in that the CNPs are *platforms* whereas the CPs are not. It is their function as a platform that makes a difference in determining the impact of net neutrality in the current model. As intermediaries between consumers and CPs, the CNPs can influence ISPs' pricing strategies, as well as how net neutrality

¹For a summary of the goal of net neutrality policy in the United States and practical issues in implementing the policy, see Gilroy (2013).

²"Amid protests, U.S. FCC proposes new 'net neutrality' rules" (Reuters, May 15, 2014).

³"European Parliament votes for net neutrality bill set to hit on-line giants hard" (Reuters, April 4, 2014).

⁴Google agreed to pay Orange for the transmission of their data (not for fast lanes). Orange claims that Google's traffic accounted for about 50% of the entire traffic in Europe. (See "*Why Orange's Dominance in Africa Forced Google To Pay For Traffic Over The Mobile Network*," Forbes, January 20, 2013.)

is conveyed to both sides of the market.

Our new two-sided market model highlights the vertical relationship between the two types of platforms, the ISPs and the CNPs. Regulating the access fee at a low level directly enhances CNPs' profits as it lowers their operating costs and induces greater participation by CPs. Such a policy improves welfare if it also increases consumer demand for the Internet. Whether or not the policy induces greater consumer demand depends on how CNPs and ISPs transmit the effect of regulation in their pricing. Because both platforms share consumers, their relationship in generating consumer demand affects the platforms' pricing strategies, optimal allocation of charges on the two sides, and, therefore, the effectiveness of the policy.

We find that regulation of the access fee is likely to improve welfare when there is inefficiency due to ISPs' market dominance in creating consumer demand for the Internet. The dominance of a platform is determined by what matters most to consumers in eliciting their participation in the Internet. ISPs gain dominance if consumer participation depends mainly on the subscription price, whereas CNPs gain dominance if content network externalities are the main driving factors of consumer demand. Regulation on the access fee shifts the focus of ISPs' optimal pricing strategy to consumer subscription by eliminating their chance to raise revenues from the access fee. Thus, any improvement in welfare due to regulation implies that, in the absence of regulation, there is inefficiency in ISPs' pricing of consumer subscription.

When ISPs are dominant, regulation on the access fee curbs their market power by limiting their incentive for aggressive pricing of consumer subscriptions for the Internet. If there is no regulation, the dominance gives ISPs an extra incentive to set high consumer Internet subscription prices. This is because, in response to the high prices, as intermediaries of content, CNPs are inclined to lower their prices in order to retain CPs and maintain consumer participation on the Internet. ISPs may use high Internet prices to lower CNPs' fees in order to optimize their access revenues without adversely affecting their consumer demand. In this situation, regulation limits (or eliminates) the access revenues of ISPs, which makes the high Internet prices no longer optimal. Thus, regulation may lower the consumer subscription prices. In this case, consumer demand for the Internet increases, and welfare improves unambiguously.

However, if CNPs are dominant, regulation only strengthens their market power and, thus, is likely to create more price distortion and inefficiency. Since the access fee is the only means by which ISPs can counter-balance CNPs' influence, if there is no

regulation, ISPs are likely to optimize their profits by means of access revenues, while keeping the consumer subscription price low. In this situation, removing the access revenues, regulation forces ISPs to raise revenues from the consumer subscription price. This results in a higher consumer subscription price. On the other hand, CNPs' dominance prevents their prices from falling by much after regulation. Thus, combined with a greater price increase for consumer subscription of the Internet, the overall effect of regulation is likely to be negative.

Although it is important to understand how the relationship between ISPs and CNPs matters in determining the impact of regulation, there has been no study of the relationship in the literature because most studies assume that CNPs do not differ from large CPs with market power.

Schuett (2010) and Krämer et al. (2013) offer excellent surveys of the existing theoretical models on net neutrality issues. Although there is no single accepted definition of net neutrality, one common interpretation is to view neutrality as non-discrimination, preventing ISPs from prioritizing traffic by setting different prices for different qualities of service. Most of this literature focuses on whether neutrality lowers the incentive of ISPs to invest (see Choi and Kim [2010], Cheng et al. [2011], Krämer and Wiewiorra [2012], Bourreau et al [2012], Reggiani and Valletti [2012], and Choi et al [2013] for examples). Another common interpretation, which we take up in this paper, is to consider net neutrality as a zero-price rule where last-mile access charges are set to zero.⁵

Economides and Tåg (2012) were the first to formulate the impact of net neutrality as a zero-price rule within a monopoly/duopoly ISP framework to analyze the impact on pricing and welfare. In the case of a monopoly ISP, they find that consumers are worse off as a result of net neutrality as the consumer price increases unambiguously. In contrast, considering the role of the CNP as a platform, we find that consumers may be better off as a result of regulation if the ISP's market dominance was a significant contributing factor to the inefficiency prior to regulation. Our result is in contrast to the "seesaw principle" in the two-sided market literature which predicts that lowering the price for CPs through net neutrality increases consumer Internet prices since the prices of the two sides of the market tend to be inversely linked.⁶

⁵Lee and Wu (2009) provide a detailed discussion of net neutrality issues from this perspective.

⁶See Caillaud and Jullien (2003), Rochet and Tirole (2003, 2006), and Armstrong (2006), for examples.

The unique role of content intermediaries as platforms between ISPs and CPs in content markets was first recognized in Hogendorn (2007), although his model ignores ISPs' function as platforms between consumers and content intermediaries. Measuring the effectiveness of regulation in terms of available content generated from entries by ISPs, intermediaries, and CPs, Hogendorn (2007) examines how the impact of open access regulation and net neutrality differ. Open access regulation in his model corresponds to regulation of access in the current paper, whereas he interprets that net neutrality also requires non-discriminatory and complete openness of the access to CNPs' network for CPs. He finds that if the entry barrier is higher for ISPs than for content intermediaries, open access regulation is more effective in creating more contents. Our paper differs from his in many important aspects. For examples, our analysis focuses on how regulation can lessen the platforms' market power, whereas his model focuses on how regulation affects the entry incentives of the firms, CPs, CNPs, and ISPs.

However, the main difference between our framework and what is discussed in the literature is that we consider the impact of the vertical relationship between the two platforms, ISPs and the CNPs. As the providers of a monopoly access to consumers, ISPs hold market power over CNPs in the generation of CPs' participation. However, it is not clear which platform has dominance in consumer demand. When regulation directly lessens the double-marginalization problem on the fees that CPs pay to participate in CNPs' content network, given the two-sidedness of the market, what matters is (i) how the platforms transfer the impact to the other side, i.e., consumers, and (ii) whether the transfer of the impact will alleviate or aggravate the inefficiency on the other side. We show that since the inefficiency is linked to platforms' market power, regulation on the access that curbs ISPs' market power is welfare-enhancing if ISPs' market power is a main source of price distortion.

The rest of the paper is organized as follows. Section 2 presents our basic two-sided market framework where two types of vertically related platforms mediate CPs and consumers. Section 3 analyzes how the vertical relationship influences the effect of regulating access fee differently. Section 4 discusses the effects of different fee structures of CNPs and the need for regulation on the Internet in comparison with access regulation in telecommunications. Section 5 concludes.

2 The Model

2.1 Two-Sided Content Markets

CNPs such as Google or Amazon function mainly as mediators between consumers and smaller CPs. Typically, CPs use CNPs to reach consumers. Amazon is one of the most widely used platforms for online purchases. Google search results are critical in determining the success of Internet marketing for local businesses.⁷ Given the myriad of available CPs, the necessity for mediation by large content platforms is increasing. Thus, we expect that this structure will persist and prevail in the future. More importantly, we expect that non-neutrality will strengthen the structure of intermediation by CNPs for smaller CPs by making it more costly for CPs to connect directly to local ISPs as they have less bargaining power than CNPs.

These platforms typically have their own data centers or content delivery network where frequently accessed CPs' data are stored for quick and efficient transmission to customers who subscribe to local ISPs. Consequently, smaller CPs often have no need to acquire direct access to consumers. However, CNPs need to use the last-mile access provided by local ISPs to make the final delivery. Local ISPs want payments for this access to consumers, while current regulation prohibits them from charging any extra fees.⁸ This is the essential nature of the net neutrality debate today.

It is the CNPs then that are directly affected by net neutrality. As evidenced by the recent public opposition of the lobbying group representing large Internet companies like Google and Facebook against the FCC's new net neutrality proposal, the debate is being played out between ISPs and CNPs, and the CNPs have been engaged in public actions to retain neutrality.^{9,10} Non-neutrality will affect smaller

⁷According to SearchEngineJournal.com, "[s]earch directly drove 25% of all online US device purchases in 2010," and "MarketingCharts reports that over 39% of customers come from search."

⁸On September 9 2013, Verizon stated that the only thing that prevented it from charging content providers for access to consumers was the FCC's rules. (<http://whatisnetneutrality.org/timeline> provided by www.publicknowledge.org)

⁹"*Google, Facebook, Netflix Make Their Official Case for Net Neutrality*" (July 14 2014, <http://www.nationaljournal.com/>)

¹⁰Since 2008, Google has been a main sponsor for the "Internet for everyone" campaign that seeks to bring open access to broadband connections ("*Announcing the 'Internet for Everyone' Campaign*," June 24 2008, <http://googlepublicpolicy.blogspot.com/>) In 2012, Amazon, Dish Network, eBay, Facebook, Google, Netflix, Sony and Twitter argued in the US. Court of Appeals for the DC Circuit that regulations protect the openness of the Internet and encourage investment in broadband infrastructure. The filing was intended to rebut the arguments of Verizon and MetroPCS, who are suing to overturn the rules ("*Google, Facebook, Netflix defend net neutrality rules in court*," 2012,

Internet Traffic and Non Net-Neutrality

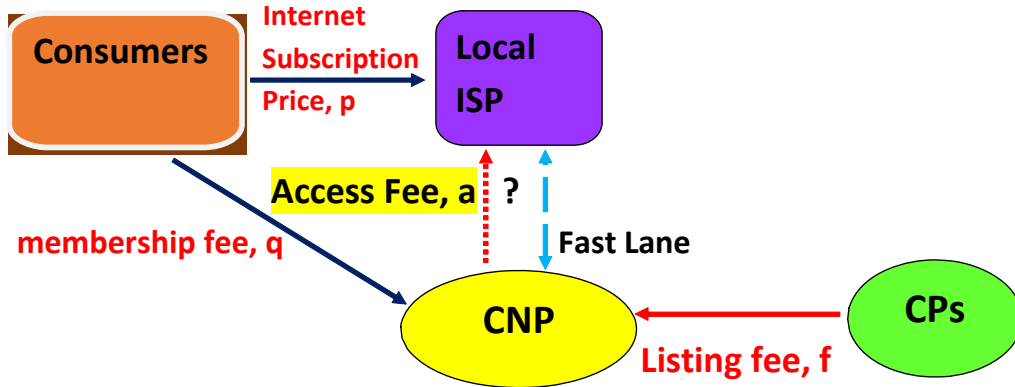


Figure 1: Internet Traffic and Non Net Neutrality

CPs only indirectly if CNPs transfer the burden of high access prices to them. For example, in purchasing a VOD (video on demand), a CNP such as Netflix offers consumers a list of movies produced by CPs such as Warner Brothers. To deliver the movies to consumers using Comcast's network in Atlanta, Netflix must gain last-mile access to the local Comcast network. Under non-neutrality, Netflix will be required to pay extra for the access. However, it may not affect Warner Brothers unless the increase in Netflix's access cost is passed on to Warner Brothers by means of a change in their licensing agreement with Netflix. Figure 1 illustrates the structure of the Internet and the impact of abolishing net neutrality in our model.

Due to this hierarchical structure of content markets, the traditional two-sided market model that features ISPs as the platforms between consumers and CPs is not a good fit for two reasons. First, it is missing the transmission mechanism of access prices from CNPs to consumers and CPs. Especially, by ignoring the effect on consumers, the traditional model under-estimates or over-estimates the impact of regulation on consumers. Second, its assumption that consumers and CPs derive network externalities from the size of each ISP's network is not valid. For CPs like Warner Brothers, what matters is not the number of consumers who use Comcast's Internet connections, but the number of consumers who use VOD services via CNPs like Netflix (many of whom do not use Comcast). Similarly, what matters to con-

thehill.com).

sumers who are looking for VOD services is the number of digital movie CPs that have a contract with Netflix, rather than the number of CPs connecting to the Comcast network. In fact, many CPs do not use Comcast.

To incorporate the hierarchical structure of content markets, we construct a two-tiered platform competition model in which two types of vertically related platforms, ISPs and CNPs, mediate consumers and CPs. In order to use any content network, consumers must first gain Internet access from a local ISP. In a content market, consumers use a CNP to reach CPs. Local ISPs hold a crucial monopoly input (i.e., the Internet connection) for both consumers and CNPs to make the transactions in content markets possible. Then, net neutrality lowers the access fee that CNPs pay to ISPs below the unregulated market equilibrium level.

The business models of these CNPs differ greatly. For example, while Google, Amazon, Vudu, YouTube, and many other platforms charge CPs advertising/listing fees or pay-per-transaction fees, Netflix charges its consumers monthly membership fees. In the case of VOD and IPTV markets, some CNPs like Comcast are vertically integrated with ISPs, whereas others like Netflix and Vudu are not.

Our model builds on the simplest framework that incorporates the most representative features of these various business models without considering the possibility of the vertical integration between CNPs and ISPs. The basic model features only one of many typical content markets in which consumers participate. We then extend our discussion to a vertically integrated business model, based on the insights that we gain from the basic framework.

The main actors of the model are a monopoly ISP, a monopoly CNP, a unit mass of CPs, and a unit mass of consumers.¹¹ We assume that the ISP is not vertically integrated. Participating consumers pay p and q to their ISP for their initial Internet connection and to the CNP for the network membership, respectively. The CPs pay f for the listing and/or advertising of their business on the CNP's network. In

¹¹The earlier versions of this paper had considered competing CNPs and competing ISPs in the model. However, we find that introducing competition among the symmetric platforms does not make much difference in comparison to a model of monopoly platforms. This is because each CNP and each ISP exert monopoly market power as “competitive bottlenecks” even when facing competition. As long as either consumers or CPs single-home with one of the CNPs (similarly for ISPs), each CNP (ISP) has monopoly power on provision of access to their single-homing customers for the multi-homing side (Armstrong, 2006, pp.669) Thus, for simplicity, we consider a framework of a monopoly CNP and a monopoly ISP. Such a configuration does not affect the qualitative results of this paper.

particular, we assume that the fee is charged per transaction.¹² Under non-neutrality, the CNP has to pay a to the local ISP in order to deliver data to the consumers in the network.

When it comes to last-mile access, it is clear that the ISP holds a dominant position as the provider of the monopoly input for the CNP. However, when it comes to the creation of consumer demand for the Internet, the ISP may or may not have dominance over the CNP. In the case of VOD or IPTV markets, for example, the demand is mainly derived for a *given* Internet connection. This shows that the ISP has dominance in creating demand for the content. On the other hand, many consumers want an Internet connection because they need information search services provided by a CNP like Google.

We consider both cases. However, we expect that two factors will facilitate ISP' dominance - vertical integration and non-neutrality. Although our model does not consider a vertically integrated ISP, it is straightforward that a vertically integrated ISP gains dominance against unintegrated CNPs using its monopoly access to consumers, whether or not it can charge for the access. Non-neutrality would strengthen the ISP' dominance further by allowing the ISP to use its monopoly input to foreclose competing CNPs. In Section 4, we discuss in this context the similarity between regulation in telecommunications and net neutrality regulation on the Internet.

The timing of interactions among consumers, CPs, CNPs and ISPs is as follows. In stage 1, the ISP sets the last-mile access fee a for the CNP. In stage 2, a dominant

¹²The qualitative results of this paper do not depend on whether the CPs pay a fixed fee or a per transaction fee. A per transaction fee most resembles the business model of Amazon, but also extends to the models of Google and YouTube. In the cases of Google and YouTube, the content is contributed by unpaid end-users (contributors of organic search content) as well as by paid sponsors. However, our model is applicable to these platforms as well because most of the "relevant" search results on Google (the ones that consumers actually view and click) are not organic, and YouTube is pursuing a partnership program with organic content contributors.

According to marketshare.hitslink.com, in 2010, 75% of users never scroll past the first page of search results. (*100 Awesome Marketing Stats, Charts, & Graphs [Data]* by Marta Kagan) Thus, on any Google search engine result pages (SERP), consumers mainly view and click the content of the first few listings, many of which are paid sponsors (the first top results and those in the column on the right) or Google local listings (the CPs that use Google+ services). Some point out that organic search results are being pushed down in the rank of SERP by sponsored results.

YouTube's current business partnership model with users called "AdSense" delegates the advertising function to individual users who contribute content, advocating a shared interest in advertising revenues. Consequently, when non-neutrality increases the pressure on YouTube's ad revenues, "AdSense" users are expected to carry a greater burden of advertising in their content, which can decrease the number of visits to their sites.

platform moves first to set the prices. It is followed by the other platform. The ISP sets consumer subscription price p , the CNP sets the listing fee f for CPs and consumer membership fee q . Finally, in stage 3, CPs and consumers simultaneously decide whether to participate in the Internet using the platforms. The next four subsections look at the decision-making problems of consumers, CPs, CNPs and ISPs.

2.2 Consumers

Each consumer purchases at most one Internet connection from ISP at a price p . Let $\theta_i \in [0, \bar{\theta}]$ be the parameter that shows a consumer i 's individual value θ of the Internet connection provided by the ISP. Let $G(\theta)$ and $g(\theta)$ be the cumulative density function (cdf) and the probability distribution function (pdf) of θ , respectively. Assume that $G(\theta)$ is continuous and twice differentiable. Consumers use the network of a CNP to find a particular CP, for which consumers may be required to pay q . Only those consumers who have decided to purchase an Internet connection can participate in content networks. A consumer i 's utility from network participation is

$$u_i = \theta_i - (p + q) + \lambda E(N^s) + \nu - c, \quad (1)$$

where ν is the intrinsic value of network services provided by the CNP and $\lambda E(N^s)$ is the consumer's valuation of the expected network externality when the CNP features N^s of CPs. Consumers purchase the Internet subscription from the ISP if and only if $u_i \geq 0$. We obtain the following individual rationality constraint:

$$\theta_i \geq p + q - (\lambda E(N^s) + \nu - c) \equiv \hat{\theta}. \quad (2)$$

Let D denote the demand for those consumers who subscribe to the Internet connection. Then,

$$D = 1 - G(\hat{\theta}). \quad (3)$$

We assume that $D'' \geq 0 \Leftrightarrow g'(\hat{\theta}) \leq 0$ and the Hazard rate $\frac{g(\hat{\theta})}{1-G(\hat{\theta})}$ is increasing, i.e. $g^2(\hat{\theta}) + g'(\hat{\theta})(1 - G(\hat{\theta})) > 0$. This implies that the willingness of the currently non-participating consumers to join the Internet increases as the membership prices $p + q$ decrease or the network externality $\lambda E(N^s)$ increases.

2.3 Content Providers

While CNPs are Internet-based enterprises, CPs may or may not be. CPs only need CNPs' mediation to reach consumers. Thus, strictly speaking, they don't even need to maintain Internet connections. Each CP is characterized by an index of profitability ϕ which is distributed over $[0, \bar{\phi}]$. Let $N(\phi)$ and $n(\phi)$ denote the cdf and the pdf, respectively. Assume that $N(\phi)$ is continuous and twice differentiable. For listing/advertising on the CNPs' network, CP j pays f to the CNP per click/transaction that consumers make online. We assume that the number of clicks or transactions have a one-to-one relationship with the number of consumers in the network. For a given f , CP j 's profit from joining the CNP is given by

$$\pi_j^{CP} = (\phi_j - f)E(D).$$

If the CNP has a larger consumer network, CPs have a greater potential for successful transactions. Thus, CPs derive network externalities from the size of the CNP's consumer network. CP j joins the CNP as long as $\phi_j \geq f$. Thus, for a given f , the size of participating CPs in the CNP is

$$N^s = 1 - N(f). \tag{4}$$

We assume that the participation of CPs increases at an increasing rate as the fee f decreases, i.e. $d^2N^s/df^2 = -n'(f) \geq 0$.

2.4 Content Network Platforms

The CNP collects and provides the list of available CPs to consumers and facilitates transactions between consumers and CPs. The CNP's profit depends on the total volume of transactions between participating CPs and consumers. We assume that the volume is proportional to the number of participants in the CNP's network. Since the CNP's bandwidth usage of the ISP's network depends on the volume of transactions supported by the CNP, the access fee is likely to be set in proportion to the volume of transactions that take place on the ISP's network. Let a be the last-mile access fee that the CNP needs to pay to the ISP per transaction when there

is no regulation. Then, the CNP's profit is defined as

$$\pi^{CNP}(f) = (q + (f - a)N^s)D - C \quad (5)$$

where C is the fixed cost.

The CNP's pricing strategy depends on its relationship with the ISP in creating consumer demand for the Internet. When the subscription price p is the primary factor in determining consumers' participation on the Internet, the ISP has a dominant position in the market. In this case, in optimizing its consumer membership fee of q and listing fee of f for the CPs, the CNP must consider the impact of p on consumer demand, as well as the impact of a . Thus, the ISP gains price leadership and CNP responds to the ISP's price p , in setting the optimal $f(a, p)$ and $q(a, p)$. On the other hand, if the CNP's content service is of primary importance in determining consumer demand, the CNP gains dominance, and the ISP must consider the impact of $f(a)$ and $q(a)$ in setting $p(f(a), q(a), a)$. In either case, however, the ISP continues to be the provider of the monopoly access to the CNP at a fee of a .¹³

Let I_{CNP} denote an index for CNP's dominance, where $I_{CNP} = 1$ if CNP has dominance, and $I_{CNP} = 0$ otherwise. Then, the CNP's optimal prices are determined as follows.

$$\frac{\partial \pi^{CNP}}{\partial f} = [N^s - n(f)(f - a)]D - (q + (f - a)N^s)g(\hat{\theta})[\lambda h(f) + I_{CNP} \cdot p_f] = 0, \quad (6)$$

$$\frac{\partial \pi^{CNP}}{\partial q} = D - (q + (f - a)N^s)g(\hat{\theta})[1 + I_{CNP} \cdot p_q] = 0, \quad (7)$$

where $p_f =: \frac{\partial p}{\partial f}$, and $p_q =: \frac{\partial p}{\partial q}$.

¹³Mainly because CNPs must obtain ISPs' monopoly input whether or not they have significant market power over consumers, dominance is more likely to fall into the hands of ISPs. This is particularly the case if consumers value network content highly (λ is large), but do not pay for the CNPs' network membership, i.e., $q = 0$, like most cases currently. Since network content is important to consumers, consumer demand for Internet subscription becomes less elastic to a high p . On the other hand, given that $q = 0$, CNPs have no direct way of countering the high p to exercise their market power over consumer demand. Thus, if p increases, CNPs are more likely to accommodate the change in p by adjusting their pricing strategy for CPs.

2.5 Internet Service Providers

Consumers subscribing to the ISP pay a fixed monthly fee p to connect to the Internet. Under non-neutrality, the CNP must pay a to the ISP to be able to get the last-mile access to the consumers subscribing to this ISP. Therefore, the ISP's profit is

$$\pi^{ISP} = D(p + aN^s) - F, \quad (8)$$

where F is the fixed cost.

The ISP's problem is to set (p^*, a^*) , the optimal connection price for consumers and the access fee for the CNP. The ISP has no incentive to lower p below $\underline{p} = v - c + \lambda N^s$ since at \underline{p} , $\hat{\theta} = 0$ and thus lowering the price will not increase demand further. Hence, we will restrict the domain of p to the range where $p \geq \underline{p}$. Let I_{ISP} denote an index for ISP's dominance, where $I_{ISP} = 1$ if ISP has dominance, and $I_{ISP} = 0$ otherwise.¹⁴ The optimal p^* satisfies

$$\frac{\partial \pi^{ISP}}{\partial p} = D - g(\hat{\theta})(p + aN^s) - I_{ISP} \cdot \left\{ g(\hat{\theta}) [q_p + \lambda n(f)] \cdot f_p \right\} (p + aN^s) + aDn(f) \cdot f_p \Big\} = 0, \quad (9)$$

where $q_p =: \frac{\partial q}{\partial p}$, and $f_p =: \frac{\partial f}{\partial p}$. Similarly, the optimal a^* satisfies

$$\begin{aligned} \frac{\partial \pi^{ISP}}{\partial a} &= D [p_a + N^s - an(f) \cdot f_a] + D_a(p + aN^s) \\ &\quad + I_{CNP} \cdot \left[(D - g(\hat{\theta})(p + aN^s))(p_f \cdot f_a + p_q \cdot q_a) \right] \\ &\quad - I_{ISP} \cdot \left\{ aDh(f) \cdot f_p + g(\hat{\theta}) [\lambda h(f) \cdot f_p + q_p] (p + aN^s) \right\} p_a = 0, \end{aligned} \quad (10)$$

where $p_a =: \frac{\partial p}{\partial a}$, $q_a =: \frac{\partial q}{\partial a}$, $f_a =: \frac{\partial f}{\partial a}$, $D_a =: \frac{\partial D}{\partial a}$.

¹⁴By construction, for a case when neither ISP nor CNP has dominance, we can impose that both indices are zero, i.e., $I_{ISP} = 0$ and $I_{CNP} = 0$.

3 Welfare Effects of Regulation

For a given a , total welfare is calculated as follows.

$$\begin{aligned}
 W &= \int_{\hat{\theta}(a)}^{\bar{\theta}} (\theta - \hat{\theta}(a))g(\theta)d\theta + \int_f^{\bar{\phi}} (\phi - f)D(a)h(\phi)d\phi + \pi^{CNP} + \pi^{ISP} \\
 &= \underbrace{\int_{\hat{\theta}(a)}^{\bar{\theta}} (\theta - \hat{\theta}(a))g(\theta)d\theta}_{\text{consumer surplus}} + \underbrace{\int_f^{\bar{\phi}} \phi D(a)h(\phi)d\phi}_{\text{CP's surplus}} + \underbrace{(p+q)D(a)}_{\text{Membership revenues for ISP and CNP}} - C - F.
 \end{aligned}$$

The welfare effect of regulating a is

$$\frac{dW}{da} = - \int_{\hat{\theta}(a)}^{\bar{\theta}} \left(\frac{d\hat{\theta}}{da} \right) g(\theta)d\theta - \int_f^{\bar{\phi}} \left(\frac{d\hat{\theta}}{da} \right) \phi h(\phi)g(\hat{\theta})d\phi + D(a) \cdot p_a - pg(\hat{\theta}) \left(\frac{d\hat{\theta}}{da} \right). \quad (11)$$

If $\frac{dW}{da} < 0$, lowering a below the market equilibrium level improves welfare.

Access revenue is not an element of welfare. However, access fee a affects welfare by altering the two platforms' pricing strategies by changing the distribution of network profits between them. In particular, the immediate impact of lowering a is to enhance the CNP's profit by lowering its operating costs. (11) shows that such regulation improves welfare as long as $\frac{d\hat{\theta}}{da} > 0$. When $\frac{d\hat{\theta}}{da} > 0$, $\frac{dD(\hat{\theta})}{da} = -g(\hat{\theta})\frac{d\hat{\theta}}{da} < 0$, thus, consumer demand for the Internet increases as a result of regulation. Thus, the question is whether regulating a can stimulate consumer demand effectively. The effect on consumer demand is crucial because, without greater consumer demand, regulation lowers the transaction volume and thus welfare. In general, in two-sided markets, the effectiveness of regulation stimulating one-side (CNP and CPs) depends on whether it can also stimulate the other side (consumers).

Since a change in consumer demand occurs as a result of changes in consumer membership prices $(p+q)$ and network effect λN^s that depends on CPs' fee f , the welfare implication of regulating a can be found in the effect of a lower a on all the other prices, p , q , and f . Therefore, in the following, we analyze the effect of lowering a on these prices. We focus on how the relationship between the ISP and the CNP influences the transmission mechanism.

3.1 When ISP has dominance

From (6) and (7), the optimal $f^*(a, p)$ and $q^*(a, p)$ satisfy

$$[N^s - n(f)(f - a)] D - g(\hat{\theta})(q + (f - a)N^s)\lambda n(f) = 0. \quad (12)$$

$$D - g(\hat{\theta})(q + (f - a)N^s) = 0 \quad (13)$$

The CNP optimally responds to a change in p in the following way.

Proposition 1 $f_p < 0$ and $q_p < 0$.

Proof. Proofs are provided in the Appendix. ■

Proposition 1 shows that the CNP lowers its prices if the Internet price for consumers increases ($f_p < 0$, $q_p < 0$). This is due to the complementarity between the CNP's intermediation service and ISP's Internet connection service in creating consumer demand for the Internet. The change in p matters to the CNP as it affects the volume of transactions. An increase in p reduces the consumer's incentive to join the Internet. If the CNP does not adjust its prices, there will be fewer consumers and, therefore, fewer transactions and lower revenues. Hence, the CNP has an incentive to compensate consumers by lowering the membership fee q or enhancing the network externality (λN^s) with a lower f .

Knowing this, ISP has a greater incentive to charge a higher p . From (9), the optimal $p^*(a)$ satisfies

$$\Psi = D(1 - an(f) \cdot f_p) - g(\hat{\theta})(p + aN^s) \underbrace{\left\{ 1 + q_p + \lambda n(f) \cdot f_p \right\}}_{\partial \hat{\theta} / \partial p} = 0. \quad (14)$$

The regularity condition requires that $\frac{\partial \hat{\theta}}{\partial p} = 1 + q_p + \lambda n(f) \cdot f_p > 0$. Since $q_p < 0$, and $f_p < 0$, (14) shows that an increase in p would not lower consumer demand for the Internet much. Thus, the ISP faces much less pressure to lower its price p to increase the size of its network participants.

As the ISP feels that consumer demand is much less elastic to the change in p as a result of $q_p < 0$, and $f_p < 0$, the ISP is more likely to optimize its revenues from consumers than from access fees by charging a high p and a low a , if there is no regulation. In such a situation, if regulation pushes a down even more, how would the ISP respond?

3.1.1 The effect of regulation on p^*

Proposition 2 shows that, if $|f_p|$ and $|q_p|$ are large enough, lowering a below a^* can lower p^* as well.

Proposition 2 *Lowering a below a^* reduces p^* if $|f_p|$ and $|q_p|$ are sufficiently large.*

In general, in a two-sided market, when a factor generates a higher price on one side, it tends to lower the price on the other side. Hence, according to this ‘‘seesaw principle,’’ net neutrality that lowers the CPs’ prices is expected to increase the consumer Internet price p^* . However, Proposition 2 shows that the ‘‘seesaw principle’’ may not hold in this framework.

Other things being equal, the higher $|f_p|$ and $|q_p|$ are, the less costly it is for the ISP to increase p than it is to increase a . Then, under non-neutrality, in order to increase the transaction volume and to optimize the access revenues, the ISP would like to charge a high p^* for consumers so that it can induce a lower advertising fee f from CNPs without lowering its access fees a^* . In this situation, when net neutrality lowers the level of access revenues that the ISP can raise, the strategy of setting a high p^* is no longer optimal. In order to make up for the lower access revenues with the revenues from increased consumer subscriptions, the ISP would have to offer a more affordable price to consumers. Thus, the ISP lowers the Internet price as a result of the net neutrality regulation.

3.1.2 The effect on welfare

Proposition 3 *A lower access fee $a < a^*$ improves total welfare as long as $\frac{dp}{da} > 0$.*

Corollary 1 *Regulation is more likely to improve welfare for a high $|f_p|$ and $|q_p|$.*

In the proof of Proposition 3, we show that a lower a directly lowers f and q , i.e., $f_a > 0$, $q_a > 0$. Then, the effect of regulation on consumer demand for the Internet is

$$\frac{d\hat{\theta}}{da} = \left(\frac{dp}{da}\right)_{+/-} (1 + \lambda n(f) \cdot f_p + q_p) + \lambda n(f) \cdot \underset{+}{f_a} + \underset{+}{q_a}.$$

From Proposition 2, if $|f_p|$ and $|q_p|$ are sufficiently high, regulation lowers the price for consumers ($\frac{dp}{da} > 0$). Then, regulation unambiguously increases demand for the

Internet, $\frac{d\hat{\theta}}{da} > 0$. From (11), in this case, regulation unambiguously increases welfare. There is greater participation not only from the CPs, but also from consumers. Due to the increased transaction volume, the decrease in ISPs' profits is minimal.

3.2 When CNP has dominance

Now suppose that λ is so high that the network content of the Internet is the main determinant for consumers' Internet participation.¹⁵ In this case, since what brings consumers to subscribe to its network is the CNP's content network, the ISP would need to consider the impact of $f(a)$ and $q(a)$ in setting the consumer subscription price $p(f(a), q(a), a)$, even though it has market power over the CNP in providing last-mile access to consumers.

In this case, from (9), the ISP's optimal subscription price p^* is determined by

$$\frac{\partial \pi^{ISP}}{\partial p} = D - g(\hat{\theta})(p + aN^s) = 0. \quad (15)$$

On the other hand, from (6) and (7), for a given a , the optimal $f^*(a)$ and $q^*(a)$ are determined at the levels that satisfy the following conditions.

$$\frac{\partial \pi^{CNP}}{\partial f} = [N^s - n(f)(f - a)]D - (q + (f - a)N^s)g(\hat{\theta}) \left(\lambda n(f) + \frac{\partial p}{\partial f} \right) = 0, \quad (16)$$

$$\frac{\partial \pi^{CNP}}{\partial q} = D - (q + (f - a)N^s)g(\hat{\theta}) \left(1 + \frac{\partial p}{\partial q} \right) = 0. \quad (17)$$

Proposition 4 $p_f < 0$ and $p_q < 0$.

If the CNP raises advertising fee f or its consumer membership fee q , ISP is inclined to lower p ($p_f < 0$, $p_q < 0$) in order to compensate for the reduced consumer incentive to subscribe to the Internet. Such responses by the ISP cause the CNP to expect that CPs' participation and consumer demand are less responsive to the

¹⁵CNPs' dominance also requires that each ISP's network size is much smaller than that of CNPs. ISPs' market power is tied to the consumers who originated within their own network, whereas CNPs' market power is based on their national/international level of content network coverage serving consumers who originated with many different ISPs. Thus, the consumer groups of two types of platforms overlap only within each ISP's network. If there is an ISP that has a network that is equivalent in size to the CNPs, it will be difficult for the CNPs to establish dominance, given that the ISP also provides the monopoly input for the CNPs.

increases in f or q . As a result, the CNP has a greater incentive to charge higher f and q . Thus, for a given a , the resulting equilibrium $f(a)$ and $q(a)$ would be higher. We can easily confirm this from (16) and (17). Other things being equal, f and q are higher than those from (12) and (13).

Consequently, the ISP does not expect to raise a great deal of revenue from consumer subscriptions. Thus, if there is no regulation, the ISP would be inclined to optimize its revenues by charging a high access fee a^* . Since both $f(a)$ and $q(a)$ increase directly with an increase in a , $f^*(a^*)$ and $q^*(a^*)$ would be high without regulation. In this case, regulation that lowers a below the optimal a^* would force the ISP to raise revenues primarily by means of the consumer subscription price p instead of the access fee a .

3.2.1 The effect of regulation on the prices

Regulation that lowers a unambiguously increases the ISP's price p while it reduces the CNP's prices f and q .

Proposition 5 *Regulation increases p , and lowers f and q .*

Contrary to the case of the ISP's dominance, the price effect on consumers is unambiguously worse when the CNP has dominance. As the ISP is unable to raise access revenues by optimally charging a^* , it must raise revenues from p . The total effect of regulation on p is as follows.

$$\frac{dp}{da} = \frac{\partial p}{\partial a} + p_f \frac{df}{da} + p_q \frac{dq}{da} < 0. \quad (18)$$

Since the consumer price p would have been very low prior to regulation due to the CNP's aggressive pricing on f and q , after regulation, the ISP can raise its revenues from consumer subscription only by increasing the price p ($\frac{\partial p}{\partial a} < 0$). Moreover, given that $p_f < 0$ and $p_q < 0$, as the CNP decreases its f and q after regulation, the ISP raises p further to make up for the lost access revenues. Thus, a decrease in a directly increases p , and increases it further by the indirect effects on f and q . This effect will be especially stronger if $a = 0$.

3.2.2 The effect on welfare

Proposition 6 *A lower access fee $a < a^*$ improves total welfare as long as λ is sufficiently large.*

Corollary 2 *Regulation is likely to improve welfare for a low $|p_f|$ and $|p_q|$.*

The effect of regulation on consumer demand is

$$\frac{d\hat{\theta}}{da} = \underbrace{\frac{dq}{da}(1 + p_q)}_+ + \underbrace{\frac{df}{da}(\lambda n(f) + p_f)}_+ + \underbrace{\frac{\partial p}{\partial a}}_- \geq 0. \quad (19)$$

Since regulation increases the consumer subscription price p while it lowers f and q , the overall effect on welfare is ambiguous. Several factors are involved in determining the welfare implications. First, since the unregulated a^* is expected to be quite high, $\frac{dq}{da}$ and $\frac{df}{da}$ are expected to be large. In particular, since the CNP's dominance arises because consumers' Internet participation depends greatly on the network externality (a large λ), the positive impact on $\frac{df}{da}$ is more likely to be dominant than the impact on p in determining the total effect on $\hat{\theta}$. Second, CNP's dominance effects, $|p_q|$ and $|p_f|$, make regulation less effective. If $|p_q|$ is small enough, the positive effect on q would outweigh the negative effect on p . Thus, overall, consumers may face a lower price $p+q$ for Internet transactions. In addition, a low $|p_f|$ would enhance the positive impact on network externality. Thus, regulation will improve welfare if the CNP's dominance effect is small enough.

3.3 Effects of Vertical Relationship

Propositions 2 through 6 show that lowering a is more likely to improve welfare if the ISP has dominance. The welfare implication depends on who has dominance because the impact of regulation onto the ISP and the CNP is asymmetric. It improves market conditions for the CNP. If the CNP has dominance, regulation amplifies the inefficiency originating in the CNP's market power. When there is no regulation, the ISP can maintain a counter-balancing position against the CNP's influence in the provision of last-mile access. Allowing the ISP to focus on access revenues for profit maximization prevents the consumer subscription price from increasing excessively. In this situation, imposing a zero access fee essentially eliminates the optimal channel

of revenues for the ISP. Thus, the ISP must rely on a less efficient channel, consumer subscription fee p . Such a distortion induces a substantial increase in p . This may lead to a contraction of consumer demand, resulting in a negative impact on the welfare.

However, if the ISP has dominance, lowering a may be efficient as it curbs the ISP's market power and, thus, reduces the ISP's incentive to aggressively price p . In the absence of regulation, the ISP is more inclined to set a high p because it anticipates that the CNP will adjust its fees in order to alleviate the negative effect of a high p on consumer demand. Positive access revenues from the CNP make the ISP more aggressive with p . Such an aggressive pricing of p becomes very costly if regulation pushes a down to a low level. Thus, regulation on the Internet access essentially curbs the ISP's market power and is more likely to induce lower p , f and q . As a result, consumer demand and transaction volume are likely to increase.

4 Discussion

4.1 Effects of CNP's Fee Structure

In many cases, CNPs do not charge consumers a membership fee, i.e., $q = 0$. On the other hand, in the case of VOD, the typical fee structure is that $q > 0$, $f = 0$, and CNPs pay fixed costs to purchase content from CPs. Since our model considers a general structure of both a membership fee and a per transaction fee, we can infer how the results would be affected if CNPs use primarily one type of fee.

In general, having both types of fees helps CNPs to respond to any changes in a . If a CNP has only one type of fee, it limits the CNP's ability to optimally allocate charges to the two sides, especially, in response to changes in a . Thus, depending on the fee structure of CNPs, a positive welfare impact of regulation may not be amplified by a greater volume of transactions. Some fee structures may even hinder the transfer of the effect of regulation to both sides of the market.

Suppose, for example, that $q = 0$ and $f > 0$. In this case, if ISPs have dominance, from (14), $\partial\hat{\theta}/\partial p$ is larger since $q_p = 0$. As a result, p is lower while f is higher from (12). Then, when regulation lowers a , the decrease in f is larger (a large df/da). If it is the case that p decreases as well ($dp/da > 0$), regulation continues to be effective. However, if p increases as a result of regulation ($dp/da < 0$), the welfare impact of

regulation is more ambiguous since the increase in p would be larger as well. On the other hand, if CNPs have dominance, from (18), p increases by less when $dq/da = 0$ whereas from (16), f is higher and decreases more as a result of lowering a (a large df/da). Hence, it is more likely that the positive impact from df/da will become dominant, making regulation more likely to be effective.

On the other hand, if $f = 0$ and $q > 0$, regulation is less likely to be effective. In this case, it does not affect CPs' participation directly. There is an impact only on consumer demand for the Internet. Without a positive feedback effect from the CPs' side, the impact of regulation is limited. In this case, regulation mainly redistributes the profits between CNPs and ISPs.

4.2 Need for Regulation on the Internet Access

Since net neutrality regulates the price of a monopoly input—access—provided by ISPs, there are parallels between regulation on the Internet access and traditional one-way access-pricing in telecommunications. In the latter case, access price regulation is essential to promote competition because a potential competitor cannot enter the market without gaining access provided by the monopoly incumbent who has no private incentive to provide access at a fair price.

The question is whether the same logic applies to the Internet. In the US, the FCC declared in 2010 its legal authority to manage ISPs under Title II and Section 706 of the Telecommunications Act. However, in January of 2014, the U.S. Court of Appeals for the District of Columbia Circuit rejected the FCC's authority because the Internet is currently classified as information services instead of telecommunications services.¹⁶ Hence, whether there is any common ground between the role of access charges in telecommunications and that of access fees in the Internet marketplace is important in determining whether the FCC has jurisdiction over Internet regulation.

In the *current* structure of the Internet, there are two differences. First, local ISPs are not in direct competition with CNPs in most cases, and the services provided by ISPs and CNPs are complementary. Second, in many cases, CNPs presently have much larger networks. In fact, the network of many ISPs is only a part of the CNPs' network. ISPs mainly serve a regional network area. They are unable to replace CNPs' national and international network services, and thus are unable to foreclose

¹⁶"*Court Tosses Rules of Road for Internet*," The Wall Street Journal, January 14, 2014.

CNPs.¹⁷ Since CNPs' market power normally comes from network externalities, any potential entrant is required to have a commensurate level of established network. This constitutes a significant entry barrier even for ISPs that cover many regions. For this reason, the complete foreclosure of CNPs can be difficult to accomplish in the current structure.

However, when taking into account the possibility of vertical integration between ISPs and CNPs and the consequences of enhanced market power for ISPs in the context of the long-run impact, net neutrality regulation shares a common ground with access regulation in telecommunications.

Currently, there are several ISPs with national network services, such as Comcast and AT&T. It would not be difficult for them to offer content intermediation services that are equivalent to those of CNPs. That is, these ISPs can offer vertically integrated services easily. In our framework, this would be accomplished if the ISP also provides the content intermediation services of the CNP. In this case, non-neutrality would effectively facilitate the foreclosure of CNPs by making CNPs unable to compete with ISPs since ISPs can easily use their access fee to make competing CNPs unviable. In that case, the ISPs would assume the role of information gatekeepers as well as the gatekeepers of Internet interconnection. In this scenario, there is a common rationale between Title II common carrier regulation and the need for regulation of broadband access. In the cases of VOD or IPTV markets, vertical integrations between ISPs and CNPs have already taken place. Thus, the concern that vertically integrated ISPs like Comcast may use access fees to foreclose a competitor like Netflix in the absence of net neutrality is at the core of arguments for the long run impact of non-neutrality.

5 Conclusions

This paper examines the effectiveness of net neutrality regulation that lowers ISPs' last-mile access fees below the market equilibrium level with a new model that highlights the role of the vertical relationship between ISPs and CNPs. In the model, transactions between consumers and content providers are intermediated by a CNP and a local ISP provides an essential input for the transactions to consumers and the CNP.

¹⁷This has been pointed out by a few economists. For example, see Weisman and Kulick (2010).

If the ISP's Internet subscription price is a primary factor in determining consumer demand for the Internet, regulating access fee is likely to be effective. Regulation is likely to lower the prices for consumers as well as the price CPs pay to the CNP. Thus, it is likely to increase consumer demand for the Internet and improve welfare. On the other hand, if the CNP's network externality is the main determinant of consumer demand for the Internet, regulation may be ineffective as it increases the subscription price substantially, while lowering the price for CPs by a lesser amount.

Our discussion of the CNP's fee structure suggests that the effectiveness of regulation also depends on the fee structure as it determines the level of feedback effect from the two sides of the Internet. To achieve considerable consumer feedback effect about regulation, the CNP must be able to transfer the burden of a higher access fee to the CPs directly. If the CNP's revenues are solely from consumer membership fee, regulation is unlikely to be effective, because it would not generate any feedback effect from the CPs.

While our main framework is constructed on the case in which the ISP is not vertically integrated, the framework can be easily extended to the case of vertical integration. An integrated ISP would have no incentive to share the content network with the CNP by permitting access at an affordable price to them. An integrated ISP will use the access fee to exclude CNPs if there is no regulation. Such a situation provides a common ground with the underlying rationale for current access regulation in telecommunications under Title II. Thus, when there are large ISPs with a national level of network services, if vertical integration by the ISPs has already taken place in many areas of content markets, or if vertical integration is easy to obtain for the ISPs, there would be a need for regulation under Title II.

Appendix B

1. Proof of Proposition 1

Combining (12) and (13), we obtain $[N^s - n(f)(f - a)] - \lambda n(f) = 0$. With respect to f , the second order conditions requires $-2n(f) - n'(f)(f - a) - \lambda n(f) < 0$. For the effect of p on q , we obtain the following by the Implicit Function Theorem.

$$q_p = \frac{1}{-SOC_q} \left[-g(\hat{\theta}) - g'(\hat{\theta})(q + (f - a)N^s) \right] < 0, \quad (20)$$

where $-SOC_q = -2g(\hat{\theta}) - g'(\hat{\theta})(q + (f - a)N^s) > 0$. The sign is negative because increasing Hazard rate implies that $g^2(\hat{\theta}) + g'(\hat{\theta})(1 - G(\hat{\theta})) = g(\hat{\theta}) \left[g(\hat{\theta}) + g'(\hat{\theta})(q + (f - a)N^s) \right] > 0$. Similarly,

$$f_p = \frac{1}{-SOC_f} \lambda n(f) \left[-g(\hat{\theta}) - g'(\hat{\theta})(q + (f - a)N^s) \right] < 0$$

where $-SOC_f = D [2n(f) + n'(f)(f - a + \lambda)] + \lambda^2 n^2(f) \left[2g(\hat{\theta}) + g'(\hat{\theta})(q + (f - a)N^s) \right] > 0$.

2. Proof of Proposition 2

From (14), $\Psi = D(1 - an(f) \cdot f_p) - g(\hat{\theta})(p + aN^s) \frac{\partial \hat{\theta}}{\partial p} = 0$. By the second order condition,

$$-SOC_p = 2g(\hat{\theta}) \frac{\partial \hat{\theta}}{\partial p} (1 - an(f) \cdot f_p) + an(f) D \left[\frac{\partial^2 f}{\partial p^2} \right] + an'(f) D [f_p] + (p + aN^s) \left[g' \left(\frac{\partial \hat{\theta}}{\partial p} \right)^2 + g(\hat{\theta}) \frac{\partial^2 \hat{\theta}}{\partial p^2} \right] > 0.$$

By the Implicit Function Theorem, $\frac{dp}{da} = \frac{1}{-SOC_p} \left(\frac{\partial \Psi}{\partial a} \right)$, where $\frac{\partial \hat{\theta}}{\partial p} = 1 + q_p + \lambda n(f)$. $f_p > 0$. The sign of $\frac{dp}{da}$ depends on the sign of $\partial \Psi / \partial a$.

$$\begin{aligned} \frac{\partial \Psi}{\partial a} &= \underbrace{-Dn(f) \cdot f_p}_{(1)+} - \underbrace{Dan(f) \frac{\partial^2 f}{\partial p \partial a} - g(\hat{\theta}) N^s \frac{\partial \hat{\theta}}{\partial p}}_{(2)+} - \underbrace{g(\hat{\theta})(p + aN^s) \left[\frac{\partial^2 \hat{\theta}}{\partial p \partial a} \right]}_{(3)+}, \text{ where} \\ \frac{\partial^2 f}{\partial p \partial a} &= \frac{1}{(-SOC_f)^2} \left[\begin{array}{c} (-ngD(2n + n'(f - a)) + \lambda ng'ND(2n + n'(f - a + \lambda))) \\ -n'D\lambda gg'D - \lambda^3 n^3 g'Ng - \lambda^2 n^3 g(2g + g'D/g) \end{array} \right] < 0, \\ \frac{\partial^2 q}{\partial p \partial a} &= \frac{1}{(-SOC_q)^2} [gg'N^s] \leq 0. \end{aligned}$$

$\frac{\partial^2 \hat{\theta}}{\partial p \partial a} < 0$ since $\frac{\partial^2 f}{\partial p \partial a} < 0$ and $\frac{\partial^2 q}{\partial p \partial a} \leq 0$. Thus, the magnitudes of $|f_p|$ and $|q_p|$ become larger as a decreases. If $|f_p|$ and $|q_p|$ are large, $\frac{\partial \hat{\theta}}{\partial p}$ is small, and thus, the only negative term $-g(\hat{\theta}) N^s \frac{\partial \hat{\theta}}{\partial p}$ becomes smaller, while a large $|f_p|$ makes the positive effect in (1) larger. Hence, if $|f_p|$ and $|q_p|$ are large enough, $\frac{\partial \Psi}{\partial a} > 0 \Leftrightarrow \frac{dp}{da} > 0$, and thus, lowering access fee decreases the consumers Internet subscription price as well. ■

3. Proof of Proposition 3

Since $\frac{d\hat{\theta}}{da} = \frac{d(p+q)}{da} + \lambda n(f) \frac{df}{da}$, $\frac{dq}{da} = \frac{\partial q}{\partial a} + \left(\frac{\partial q}{\partial p} \right) \frac{dp}{da}$, and $\frac{df}{da} = \frac{\partial f}{\partial a} + \left(\frac{\partial f}{\partial p} \right) \frac{dp}{da}$, $\frac{d\hat{\theta}}{da} =$

$\frac{dp}{da} \cdot (1 + \lambda n(f) \cdot f_p + q_p) + q_a + \lambda n(f) \cdot f_a$. The direct effects of a on f and q are

$$f_a = \frac{1}{-SOC_f} \left[D + g(\hat{\theta})N^s \lambda \right] n(f) > 0, \text{ and} \quad (21)$$

$$q_a = \frac{1}{-SOC_q} \left[g(\hat{\theta})N^s \right] > 0, \quad (22)$$

Thus, if $\frac{dp}{da} > 0$, $\frac{d\hat{\theta}}{da} > 0$, and $\frac{dW}{da} < 0$, and thus, regulation improves welfare always. From above, $\frac{dp}{da} > 0$ is likely to occur if $|f_p|$ and $|q_p|$ are large. ■

4. Proof of Proposition 4

For a zero access fee $a = 0$,

$$p_f = \frac{1}{-SOC_p} \left[-\lambda n(f) \left(g(\hat{\theta}) + g'(\hat{\theta})(p + aN^s) \right) + ag(\hat{\theta})n(f) \right] \quad (23)$$

$$= \frac{1}{-SOC_p} \left[-\lambda n(f) \left(g(\hat{\theta}) + g'(\hat{\theta}) \frac{D}{g(\hat{\theta})} \right) + ag(\hat{\theta})n(f) \right] < 0. \quad (24)$$

Similarly,

$$p_q = \frac{-1}{-SOC_p} \left[g(\hat{\theta}) + g'(\hat{\theta})(p + aN^s) \right] < 0. \quad \blacksquare$$

5. Proof of Proposition 5

(1) From (16) and (17), regularity conditions require that $\frac{\partial \hat{\theta}}{\partial q} = 1 + \frac{\partial p}{\partial q} > 0$ and $\frac{\partial \hat{\theta}}{\partial f} = \lambda n(f) + \frac{\partial p}{\partial f} > 0$. Combining (16) and (17), we obtain $[N^s - n(f)(f - a)](1 + \frac{\partial p}{\partial q}) - (\lambda n(f) + \frac{\partial p}{\partial f}) = 0$. Then,

$$\frac{df}{da} = \frac{1}{-SOC_f} \left[n(f)D + g(\hat{\theta})N^s \left(\lambda n(f) + \frac{\partial p}{\partial f} \right) - (q + (f - a)N^s)g(\hat{\theta}) \frac{\partial^2 p}{\partial f \partial a} \right] > 0$$

$$\frac{dq}{da} = \frac{1}{-SOC_q} \left[g(\hat{\theta})N^s \left(1 + \frac{\partial p}{\partial q} \right) - (q + (f - a)N^s)g(\hat{\theta}) \frac{\partial^2 p}{\partial q \partial a} \right] > 0$$

where $SOC_f < 0$, $SOC_q < 0$, $\frac{\partial^2 p}{\partial f \partial a} = \frac{1}{(-SOC_p)^2} \left[g'(\hat{\theta})p + 2g(\hat{\theta}) - g'(\hat{\theta})\lambda N^s \right] > 0$, and

$$\frac{\partial^2 p}{\partial q \partial a} = \frac{-1}{(-SOC_p)^2} \left[g'(\hat{\theta})g(\hat{\theta})N^s \right] > 0.$$

(2) Lowering a directly increases p .

$$\frac{\partial p}{\partial a} = \frac{1}{-SOC_p} \left(\frac{\partial \Psi}{\partial a} \right) = \frac{1}{-SOC_p} \left(-g(\hat{\theta})N^s \right) < 0,$$

where $SOC_p = - \left[2g(\hat{\theta}) + g'(\hat{\theta})(p + aN^s) \right] < 0$. Since $p_f < 0$ and $p_q < 0$, the total effect of regulation on p is

$$\frac{dp}{da} = \frac{\partial p}{\partial a} + p_f \frac{df}{da} + p_q \frac{dq}{da} < 0. \blacksquare$$

5. Proofs of Proposition 6 and Corollary 2

From (19), it is straightforward that $\frac{d\hat{\theta}}{da} > 0$ is likely to hold for a large enough λ , and a low $|p_f|$ and $|p_q|$. \blacksquare

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