6. Network neutrality and network management regulation: quality of service, price discrimination, and exclusive contracts

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INTRODUCTION

The topic of network neutrality regulation is both important and controversial. The issue concerns mainly two questions. First, should the networks that provide last mile access to residential users be able to manage or restrict the packets of data flowing through their networks in a way so that some types of packets or packets from certain content providers are favored? Second, should the network operators be allowed to charge content and applications providers' fees for faster access to consumers (either through a dedicated last mile line or through obtaining prioritized access)? Proponents of network neutrality regulations fear that without regulation, network operators will be in a position to favor their own content, pick the winners among content providers, create artificial congestion in the last mile, reduce the availability of content and negatively affect innovation incentives for content providers "at the edge" of the internet.[1] Opponents of network neutrality regulations argue that the ability to manage and restrict traffic on their lines is needed to ensure efficient use of the network and to ensure Quality of Service (QoS). They also state that revenue from charging content providers for faster access is needed to encourage new investments in network infrastructure.

In the United States, the Federal Communications Commission (FCC) proposed in October 2009 a Notice of Proposed Rulemaking (NPRM), a strict non-discrimination rule that imposed non-discrimination, defined in paragraph 104 as follows: "We understand the term 'nondiscriminatory' to mean that a broadband Internet access service provider may not charge a content, application, or service provider for enhanced or prioritized access to the subscribers of the broadband Internet access service provider").

In its final rule on network neutrality adopted in December 2010, the FCC retreated considerably from its NPRM proposal and imposed (1) Transparency: Fixed and mobile broadband providers must disclose

the network management practices, performance characteristics, and terms and conditions of their broadband services; (2) No blocking: Fixed broadband providers may not block lawful content, applications, services, or non-harmful devices; mobile broadband providers may not block lawful websites, or block applications that compete with their voice or video telephony services; (3) No unreasonable discrimination: Fixed broadband providers may not unreasonably discriminate in transmitting lawful network traffic; (4) Exempted wireless networks from the last rule.[2] Even though this regulation is weak, Verizon sued to stop it, claiming that the FCC does not have legal authority to impose any rules on internet traffic.[3] Additionally, on April 11, 2011, the House passed, along party lines, a Republican-sponsored resolution reversing the FCC's "network neutrality" rules. The resolution was rejected by the Senate.[4]

Since the topic of network neutrality covers a wide range of issues, and means different things to different people, it is not surprising that several approaches to network neutrality regulation have been discussed by policy makers. In this chapter we formally compare three such approaches to the alternative of no regulation. We highlight how each of these regimes can be interpreted to either allow or restrict 1) variations in guaranteed QoS levels (non-discrimination), 2) tariff-based price discrimination, where tariff-based fees are imposed on content providers without identity-based discrimination, and 3) exclusive contracts where identity-based discrimination can be used to block content providers from reaching consumers. The regimes we compare are the following.

- *Absolute Non-Discrimination (No QoS)*. In this regime is the strongest form of regulation and is in line with the definition of network neutrality put forth by Tim Wu: "Network neutrality is best defined as a network design principle. The idea is that a maximally useful public information network aspires to treat all content, sites, and platforms equally. This allows the network to carry every form of information and support every kind of application."[5] In this regime, offering separate guaranteed levels of QoS to different content providers is not permitted, even if offered without price discrimination. Neither price discrimination nor exclusive contracts are allowed in this regime.
- *Limited Discrimination without Quality of Service Tiering (No Fees)*. This regime is in line with the fifth principle suggested as a regulatory proposal for the internet in the FCC NPRM (FCC 2009, para. 104)[6]: "Subject to reasonable network management, a provider of broadband Internet access service must treat lawful content, applications, and services in a nondiscriminatory manner." In this

regime, it is possible for the network operator to offer different guaranteed levels of QoS to different content providers depending on what level of QoS they demand (e.g. a VOIP provider needs a higher level of QoS than a standard-text-based search engine). This is captured by the phrase "reasonable network management" in (FCC 2009, para. 135): "Reasonable network management consists of: (a) reasonable practices employed by a provider of broadband Internet access service to (i) reduce or mitigate the effects of congestion on its network or to address quality-of-service concerns; (ii) address traffic that is unwanted by users or harmful; (iii) prevent the transfer of unlawful content; or (iv) prevent the unlawful transfer of content; and (b) other reasonable network management practices." However, in this regime, neither charging content providers for access to higher guaranteed levels of QoS nor exclusive contracts are allowed (FCC 2009, para. 104): "We understand the term 'non-discriminatory' to mean that a broadband Internet access service provider may not charge a content, application, or service provider for enhanced or prioritized access to the subscribers of the broadband Internet access service provider").

- *Limited Discrimination and QoS Tiering (No Exclusivity)*. This regime is inspired by the FCC Broadband Policy Statement released in September 2005[7] and is also in line with the Internet Consumer Bill of Rights. In this regime, exclusive contracts and identity-based discrimination are banned, but the network operator can offer various guaranteed levels of QoS (tiers), each at a different price to content providers. A content provider can choose not to pay for a higher guaranteed level of QoS, in which case only a basic level of access to consumers is provided (for free).
- *No Regulation*. In this regime, any discrimination is allowed, including identity-based discrimination and exclusivity. A network operator can choose to sell exclusive access to one content provider instead of only selling various guaranteed levels of QoS to all providers. A content provider not obtaining exclusive access has no way to reach consumers and exits the market leading to less content provider variety available for consumers.

We compare these regimes in the context of a stylized model with a monopolist network operator and two competing content providers. Specifically, we aim to answer the following questions. Which form of regulation yields the highest guaranteed levels of QoS? What is the market outcome in case of no regulation? Is regulation needed to maximize social welfare?

We establish the following results. First, in relation to incentives of the network operator to improve guaranteed levels of QoS, we find that QoS offered to the two content providers will be highest if the network operator is allowed to price discriminate and charge content providers for access to better QoS. With an exclusive contract, the level of QoS offered to the exclusive content provider may still be higher than with price discrimination if content providers do not profit much from increases in QoS but consumers value QoS highly. Hence, regulation to restrict exclusive contracts and price discrimination is likely to lead to lower levels of QoS. Further, the difference in QoS offered to content providers is highest under exclusive contracts or price discrimination. It is only equal when QoS improvements are banned and is likely to differ even when price discrimination is not allowed but variations in QoS are. The reason is heterogeneity in the valuation of QoS among consumers and content providers and that QoS provision is costly for the network operator (Proposition 1).

Second, a private monopolist network operator will always prefer price discrimination to only variations in QoS or to no QoS improvements. The network operator will prefer to implement exclusive contracts if consumers view content providers as similar and if there is a large difference in content providers' ability to profit from consumers, thereby implying that exclusive access is very valuable for the content providers (Proposition 2).

Third, though ranking of the private profitability of the regimes is unambiguous, ranking social welfare to determine optimal regulation yields different results depending on parameter values. We identify four channels thorough which regulation affects total welfare: 1) through the effect of QoS variations on consumer common valuation of the content providers, 2) through affecting total transportation costs determined by consumer preferences over content providers, 3) through redistributing consumers among content providers and thereby changing total surplus created on the content provider side and 4) through changing the total costs of QoS provision (Proposition 3).

The policy implication from these results is that we should expect that network operators will have incentives to implement price discrimination and possibly also to exclude some content providers from reaching consumers absent any regulatory intervention. This can be prevented by implementing regulation, but it can come with costs in terms of reducing the network operators' incentives to invest in upgrading their network to achieve better guaranteed Quality of Service. A balanced path, for example as suggested by the FCC NPRM (FCC 2009), may be one way forward as it allows some quality of service variations and investment in improving quality of service that is driven entirely by payments from con-

sumers, but shuns away from allowing investments in quality of service to be driven by payments from content providers as well.

The rest of the chapter proceeds as follows. The next section provides a literature review. In section 3, we present the model that we utilize to compare the regimes. Section 4, solves the model and presents our main results. Section 5 discusses our model. We conclude in section 6.

LITERATURE REVIEW

Despite a considerable literature discussing legal issues of network neutrality regulations and net management regulations, the literature on economic analysis of these issues is not extensive.

An early paper, Hermalin and Katz (2007), analyzes a model where network neutrality is equivalent to the imposition of a single product quality requirement. They analyze a monopoly platform facing heterogeneous content providers and homogeneous consumers. A key result of imposing a single product quality requirement is that the number of content providers available to consumers is reduced, as some low valuation content providers choose not to sell when only one price is offered (exclusion effect). This reduces welfare. Welfare is also reduced because some high valuation providers sell lower and less efficient qualities (reduced quality effect). However, medium valuation providers end up selling higher and more efficient qualities which increase welfare (improved quality effect). Total welfare may thus increase or decrease, but the authors suggest that total welfare will increase only if the marginal types served under the restriction obtain a much higher quality than they would obtain absent the restriction. From a welfare perspective some low valuation content providers should be excluded if the costs of providing quality exceed the benefit they bring to the platform. Further, an unrestricted platform will exclude even more content providers since it has to give information rents to higher quality content providers. Hermalin and Katz (2007) also analyze the case where the ISP is forced to quote a zero price to content providers and show that then only one quality level is offered, and that the level of this quality is lower than the socially efficient level as well as the level that would be offered under a single quality level requirement. The reason is that the IPS ignores the preferences of the content providers because they do not pay for access to consumers.

Another early formal analysis of network neutrality is Hogendorn (2007), who analyzes the differences between open access and network neutrality and emphasizes that these are different policies that may have different implications. Hogendorn interprets network neutrality in a

slightly different way than most of the literature. In Hogendorn (2007), open access refers to allowing intermediaries access to conduits so that intermediaries such as AOL and MSN can access conduits like AT&T at a nondiscriminatory price, while full network neutrality is interpreted to mean that content providers have unrestricted access to intermediaries so that e.g. Yahoo cannot restrict which content providers can be reached through its portal, in addition to open access between conduits and intermediaries. He studies a three-stage game: entry of conduits and intermediaries, negotiations between intermediaries and content firms, and finally consumers' subscription to conduits and intermediaries' consumption of content. There is free entry of conduits and intermediaries, while there is monopolistic competition between content providers. He then analyzes the differences between open access and network neutrality and emphasizes that these are different policies that may have different implications. In particular, he finds that under network neutrality, a smaller number of intermediaries enter the market due to decreased profits (so this would mean fewer AOLs, Yahoos and MSNs). The reason profits decrease under network neutrality is that they cannot charge high fees to content providers. Open access, on the contrary, increases the entry of intermediaries since they now have free access to conduits, and can also charge content providers. However, open access is not a substitute for network neutrality regulation. Network neutrality reduces the number of intermediaries, implying that network neutrality reduces content on the internet. He argues that the effect on restricting content is likely to be larger now than it would have been a decade ago, since profits for content providers are larger now implying that incentives to extract these profits also are larger. The overall total welfare results are ambiguous and depend on parameter values.

Economides and Tåg (2012) explicitly studies two-sided pricing in the context of network neutrality on the internet and abstracts from issues related to price discrimination, dynamic innovation incentives or prioritization. Network neutrality is interpreted to mean zero prices to one side of the market (the content side). The paper considers both a setting with a monopolist platform and a setting with two duopolistic platforms and multi-homing content providers. Consumers are horizontally differentiated and buy from either of the platforms. The central argument in the paper is that Internet Service Providers must be seen as platforms in a two-sided market intermediating transactions between consumers and content providers. In such a market, private ISPs may not internalize the externalities across sides (between consumers and content providers). This gives a rationale for government intervention. Depending on parameter values, network neutrality regulations that implicitly impose a price of

zero towards content providers may bring the price balance closer to the socially optimal price balance and thereby increase social welfare. However, for other parameter values the opposite is true.

Focusing on the long run effects of network neutrality regulations, Choi and Kim (2010) study both a static and a dynamic setting focusing on how innovation incentives are affected by network neutrality. The authors use a Hotelling model to study two aspects of network neutrality regulation: congestion and innovation incentives (both for the ISP and the content providers). There is a monopoly ISP and two competing content providers. Network neutrality implies that the ISP cannot sell prioritized access to consumers to one of the content providers. They find ambiguous results regarding the impact of network neutrality regulations on welfare; however, they underscore that in a static setting social welfare is higher under network neutrality if content providers are sufficiently similar. In a dynamic setting they underscore two trade-offs. First, network neutrality regulation affects the investment incentives of the ISP by either allowing the ISP to charge more/less for access (network access fee effect) or by allowing the ISP to sell rights to prioritized delivery of content (rent extraction effect). Investing in improving capacity implies that the ISP must charge less for prioritized delivery, so incentives to expand capacity can possibly be lower without network neutrality regulation (contrary to what opponents of network neutrality regulation claim). Further, to achieve better rent extraction the ISP may have incentives to degrade the non-priority packets in order to restore incentives to invest (though the authors do not formally show this). Second, since the ISP can extract rents from content providers through selling first priority access, network neutrality regulation improves investment incentives for content providers by removing the rent extraction possibility. However, it is not clear that the ISP wishes to extract all rents from content provider investments since he has incentives to encourage some investment by content providers and might thereby be willing to commit to network neutrality. In sum, the authors find ambiguous results regarding the impact of network neutrality regulations on welfare, but highlight that, in a dynamic setting, network 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.

Focusing on congestion effects in the short run, Cheng, Bandyopadhyay and Guo (2010) model two content providers who can avoid congestion by paying ISPs for preferential access. The model is similar to Choi and Kim (2010) since the authors use a monopoly ISP model with two content providers. They find that abolishing network neutrality will benefit ISPs and

hurt content providers. Depending on the parameter values, consumers are either unaffected or better off. In particular, social welfare increases when network neutrality is abandoned and one content provider pays for access; but it 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 results in 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. Further, incentives for the broadband provider to expand its capacity are higher under network neutrality regulation since more capacity leads to less congestion. Since congestion decreases, Internet services become more valuable (to the benefit of ISPs). If network neutrality is abolished, their model predicts reduced investment incentives because congestion becomes less of a problem.

Emphasizing that the quality of the ISP's network affects trade across the platform, Cañón (2009) studies active discrimination between buyers and sellers in a fully two-sided market by generalizing the Hermalin and Katz (2007) approach and the Economides and Tåg (2012) paper by considering dynamic investment incentives in a two-sided market with heterogeneous consumers. The formal model has two stages: investment by the ISP and entry/trade between buyers and sellers on the platform. The ISP invests without knowing the private benefits for trade for the buyers and the sellers. Investment benefits end users as the marginal utility of consumption of the content provider's goods is higher. The users enter the platform to trade only if their expected utility of trade with the sellers is higher than the access fee. Sellers design an optimal non-linear tariff for all end-users. The results support network neutrality regulation by underscoring that imposing zero fees to content providers will lead to more content providers and users entering the platform. More investment will be made by the ISP since more users join the platform when their value from trade increases for each content provider. While imposing regulation leads to higher welfare costs in terms of ISP investment costs and end user entry costs, the benefits from increased total trade surplus on the platform tend to outweigh the costs.

Creating lanes with prioritized delivery of content may help small content providers who are sensitive to the quality of service. Jamison and Hauge (2008) set up a model of a monopolist ISP intermediating heterogeneous content providers to consumers and study the innovation incentives of content providers and ISPs. Their main arguments are that offering differential levels of quality of service helps smaller content

providers (with lower quality) because they can purchase premium access and thereby better compete with higher quality content providers (because total quality depends on both transmission speed and underlying quality). The reason is that in their setup the marginal value of increased speed is higher for low quality content providers than for high quality content providers. Without premium access, it would not be profitable for them to enter the market. Abandoning network neutrality will thus decrease innovation among content providers. Hence, offering premium service to content providers will increase demand for broadband and thereby give the ISP more revenues from consumers as well.

Departing from network neutrality could potentially give an ISP a way of degrading the services of competitors who rely on high levels of quality of service. Chen and Nalebuff (2007) analyze competition between complements and briefly touch upon the issue of network 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).

More recently, two papers have emerged indicating that network neutrality regulation is likely to be beneficial if it leads to entry of more content providers. Krämer and Wiewiorra (2009) study a two-sided monopoly market model that focuses on congestion and prioritization of access. Content providers are vertically differentiated and consumers are homogeneous. Network neutrality implies that the ISP cannot build a "fast-lane" that gives prioritized access over best-effort delivery at a price. Hence, without network neutrality the ISP charges only for prioritized access and not for best-effort access. The ISP faces a tradeoff in that reducing congestion draws in more content providers and consumers (the expansion effect), but on the other hand more content providers and consumers in turn drive up congestion (the congestion effect). In the short run, prioritization degrades performance on the best-effort line, and this hurts non-paying content providers. However, it allows content providers with business models that are sensitive to quality of service to enter the market. Hence, from a welfare perspective, discrimination harms all content providers in the short run since some pay and some face increased congestion. However, welfare is increased since congestion is better allocated. Content providers are worse off because the ISP extracts surplus from them through the fee for prioritized access. In the long run, however, ISP investments will be lower under network neutrality and less content

will be available. ISP investments are lower under network neutrality because they cannot charge content providers. Lower investments lead to higher congestion and less content is available.

Economides and Hermalin (2012), despite assuming network congestion, find that network neutrality is welfare-superior to bandwidth subdivision and prioritization. They also find that the incentive to invest in bandwidth is greater when the ISPs can price discriminate, and investment in bandwidth may mitigate the welfare losses of departures from network neutrality. A central assumption is that content and applications providers differ in how valuable their content or application is perceived to be by consumers. As such, high value content generates higher revenues, gets more traffic and therefore congests the network more even when capacity is expanded.

In sum, though several aspects of network neutrality regulation have been considered, no work has so far been done on comparing the effects of different degrees of regulation within the framework of the same model. The formal model in this chapter provides such an analysis. It is related to Cheng, Bandyopadhyay and Guo (2010), Choi and Kim (2010) and Krämer and Wiewiorra (2009), in that we use a similar setup of a monopolist network operator (ISP) in a two-sided market connecting two competing content providers with consumers. One important difference is that we specifically allow for different "lanes" with different levels of QoS and for pricing each lane separately. We assume that providing QoS is costly to the network operator and because of differences in consumers' valuation of content providers and content providers' valuation of QoS, we typically get different equilibrium levels of QoS for different content providers. This approach assumes that potential congestion effects are completely captured in the cost function for guaranteeing a specific combination of QoS. Our research is complementary to Jamison and Hauge (2008), Hermalin and Katz (2007), Cañón (2009), Economides and Tåg (2012) and Economides and Hermalin (2012) as we do not specifically here focus on price balance between consumers and content providers or on the effects of restricting the product line offered to content providers.

THE MODEL

There are three types of actors in our model: consumers that buy internet access, a monopolist network operator (Internet Service Provider, "ISP"), and two content providers: A and B. The monopolist network operator sells internet access to consumers at price P and can also charge prices s_A and s_B to content providers A and B respectively for access to better

QoS. The network operator can also decide to sell to one content provider exclusive access to consumers, in which case s_E denotes the price for exclusivity. The timing is the following.

1. The regulator chooses among the four possible regimes.
2. The network operator observes the regulatory regime and, if possible, decides on whether to invest in QoS, whether to charge A and B for access to better QoS, or whether to sell only exclusive access. Then, if the network operator chose to improve QoS, it chooses the level of QoS to provide to A and B.
3. The network operator sets price for internet access and either sets individual fees for QoS improvements or the fee for exclusivity. Content providers decide on buying better access or on buying exclusive access.[8]

Consumers are differentiated in their preferences for content providers. Our model has a continuum of consumers distributed on the interval [0, 1] according to their location x with cumulative distribution function F(.) with density f(.). There are two content providers, A and B, located at each end of the interval (A at 0 and B at 1). The loss of utility or "transportation cost" faced by a consumer located at x_i for using the services of A is tx_i and for using the services of B is $t(1 - x_i)$. To gain access to content providers, a consumer must pay the network operator the price P. We assume that all consumers buy content either from A or B, so that there are no demand expansion effects. The level of QoS provided by the network operator to content provider A and B are denoted by q_A and q_B. Content providers are valued by consumers at $v_A(q_A)$ and $v_B(q_B)$, excluding transportation costs.[9] Since higher QoS is desirable, we have that $v'_A(q_A) > 0$, and $v'_B(q_B) > 0$. We impose the following assumption.

Assumption 1: $v_A(q) > v_B(q)$ and $v'_A(q) > v'_B(q)$.

This assumption says that for a given level of QoS, consumers value the content from A higher than the content from B, absent transportation costs. Additionally, A offers services that rely more on real-time transmission of packets and thus A benefits relatively more from an improvement in QoS than B does. This assumption is imposed in order to account for diversity in the services that are provided on the internet. In particular, regulation is likely to affect latency sensitive services such as video, voice over IP and streaming music services differently than it impacts text-based services such as simple web pages and email services. By allowing one content provider (provider A) to be more sensitive to QoS than the rival

(provider B), we account for this difference in our model and allow for different effects of regulation on different content providers.

Given the above specification, the utility of a consumer located at x_i is given by

$$u_i(q_A, q_B, P) = \begin{cases} v_A(q_A) - tx_i - P \\ v_B(q_B) - t(1 - x_i) - P. \end{cases} \tag{6.1}$$

The location of the consumer who is indifferent between A and B is thus

$$x^*(q_A, q_B) = \frac{1}{2} + \frac{v_A(q_A) - v_B(q_B)}{2t}, \tag{6.2}$$

and the resulting mass of consumers at each content provider is $n_A = F(x^*)$ and $n_B = 1 - F(x^*)$.

Each content provider profits from selling advertising space. For each content provider, profit from advertising is an increasing function of the mass of consumers using its services, $\pi'_A(n_A) > 0$, $\pi'_B(n_B) > 0$. Content providers' total profits are $\Pi_A = \pi_A(n_A) - s_A$ and $\Pi_B = \pi_B(n_B) - s_B$, where s_A and s_B denote fees the content provider must pay for access to consumers in the case the network operator charges content providers for access to better QoS. If the network operator sells exclusive access only, then price s_A or s_B is replaced by s_E. We further impose the following assumption:

Assumption 2: $\pi_A(n) > \pi_B(n)$.

This assumption states that for a given mass of consumers (market share), A is more efficient at turning users' attention into profits through advertising than B is. Again, this allows us to account for the fact that depending on the content provider's ability to profit from users, regulation may affect one content provider more than the other.

The network operator has a cost function of improving QoS given by $c(q)$. We assume that $c(0) = 0$, $c'(q) > 0$ and $c''(q) > 0$. These costs can arise from network management and prioritization, or they can arise from other sources such as laying down new cables or improving old ones. Finally, to illustrate some of the propositions in more detail, we will sometimes invoke the following assumption:

Assumption 3 (Linearity): Consumers are uniformly distributed, $F(x) = x$, the value of QoS is $v_A(q_A) = v + w_A q_A$, $v_B(q_B) = v + w_B q_B$, costs of providing quality are $c(q) = cq^2$, and content provider profits excluding quality costs are proportional to sales, $\pi_A(x) = ax$ and $\pi_B(x) = b(1 - x)$.

We will consider the network operator's optimal business strategy, QoS investment choices and pricing in four regimes. **No Regulation** means that the network operator is free to set all three prices (price to consumers and a fee to each content provider), QoS levels, and to exclude one content provider if it so wishes. **No Exclusivity** means that the content provider is free to set all three prices and QoS levels, but cannot exclude a content provider. **No Fees** imply that the network operator can only set the price to consumers P and QoS levels, but fees to content providers are zero, $s_A = s_B = 0$. **No QoS** implies that QoS investments and thus variations in QoS are not possible ($q_A = q_B = 0$) and that the network operator can only set price P. Fees to content providers are zero, $s_A = s_B = 0$.

ANALYSIS

Pricing

We start by determining prices and fees set in stage 3. There are four possible cases to analyze: exclusive access, price discrimination, no fees, and no QoS variations.

Exclusive access. When exclusive access is implemented, the network operator sells exclusive access to its consumers to only one content provider. Given assumption 2, it is always more profitable to sell exclusive access to A. Hence, all consumers use A and we have that $x^* = 1$. The network operator chooses P and s_E to maximize $\Pi^E = P^E + s_E - c(q_A)$ subject to

$$v_A(q_A) - t - P^E \geq 0 \text{ (the market remains covered)} \tag{6.3}$$

$$\pi_A(F(1)) - s_E \geq 0 \text{ (A prefers to purchase exclusive access).}^{10} \tag{6.4}$$

The monopolist network operator does best in raising the price and the fee until both inequalities become equalities. Its profits are then $\Pi^E = v_A(q_A) - t + \pi_A(F(1)) - c(q_A)$.

Price discrimination. When price discrimination is implemented, the network operator sells better QoS to content providers and charges them individual prices for access to "lanes" of different quality. Given that it is profitable to set prices such that both content providers purchase better QoS, the consumer indifferent between A and B is located at $x^*(q_A,q_B)$ defined above. The network operator maximizes

$$\Pi^{PD} = P^{PD} + s_A + s_B - c(q_A) - c(q_B) \text{ subject to}$$

$$v_A(q_A) - tx^*(q_A, q_B) - P^{PD} \geq 0 \text{ (the market remains covered)} \quad (6.5)$$

$$\pi_A(F(x^*(q_A, q_B))) - s_A \geq \pi_A(F(x^*(0, q_B))) \text{ (A prefers better QoS)} \quad (6.6)$$

$$\pi_B(1 - F(x^*(q_A, q_B))) - s_B \geq \pi_B(1 - F(x^*(q_A, 0))) \text{ (B prefers better QoS)} \quad (6.7)$$

Note that we assume that each content provider operates under the assumption that the rival always purchases better QoS. The network operator does best in raising all prices until the inequalities become equalities. The network operator profits are then

$$\Pi^{PD} = v_A(q_A) - tx^*(q_A, q_B) + \pi_A(F(x^*(q_A, q_B))) - \pi_A(F(x^*(0, q_B))) +$$

$$\pi_B(1 - F(x^*(q_A, q_B))) - \pi_B(1 - F(x^*(q_A, 0))) - c(q_A) - c(q_B) \quad (6.8)$$

No fees. In the case the network operator cannot set fees to content providers, it chooses just P^{NF} to maximize $\Pi^{NF} = P^{NF} - c(q_A) - c(q_B)$, subject to $v_A(q_A) - tx^*(q_A, q_B) - P^{NF} \geq 0$ (the market remains covered). Profits are $\Pi^{NF} = v_A(q_A) - tx^*(q_A, q_B) - c(q_A) - c(q_B)$.

No QoS. Finally, if there are no QoS improvements and fees to content providers, the network operator sets P^{NF} to maximize $\Pi^{NQoS} = P^{NQoS}$ subject to $v_A(0) - tx^*(0, 0) - P^{NQoS} \geq 0$ (the market remains covered). Profits in this case are $\Pi^{NQoS} = v_A(0) - tx^*(0, 0)$.

Investment

We now consider investments in improving QoS and the network operator's choice of business model. We can show the following proposition regarding the level of QoS under different business strategies.

Proposition 1. Equilibrium QoS levels can be ranked as follows: $q_A^{PD} \geq q_A^{NF} \geq q_A^{NQoS} = 0$, $q_B^{PD} \geq q_B^{NF} \geq q_B^{NQoS} = q_B^E = 0$ and $q_A^E \geq q_A^{PD}$ for $v_A'(q_A)/2 > \pi_A'(q_A)$, which under Assumption 3 reduces to $t > a$. The difference in QoS offered to A and B can under Assumption 3 can be ranked as follows: $\Delta q^{PD} > \Delta q^{NF} > \Delta q^{NQoS} = 0$ and $\Delta q^E > \Delta q^{PD}$ for $bw_B + t(w_A + w_B) > aw_A$.

To see this, consider investments in each of the three cases outlined above that allow for QoS investments (investment is zero by assumption in case of no provision of QoS). QoS levels are determined by the equations $v_A'(q_A^E) = c'(q_A^E)$ in case of exclusivity, $v_A'(q_A^{PD})/2 + \pi_A'(q_A^{PD}) = c'(q_A^{PD})$ and

$v_B'(q_B^{PD})/2 + \pi_B'(q_B^{PD}) = c'(q_B^{PD})$ in case of price discrimination, and by $v_A'(q_A^{NF})/2 = c'(q_A^{NF})$ and $v_B'(q_B^{NF})/2 = c'(q_B^{NF})$ in case no fees are charged to A and B.[11] For the difference in QoS offered to A and B, under linearity we get $\Delta q^E = (1/2c)w_A$, $\Delta q^{PD} = \frac{w_A - w_B}{4c} + \frac{aw_A - bw_B}{4ct}$ and $\Delta q^{NF} = \frac{w_A - w_B}{4c}$, which, under assumptions 1 and 2, give the rankings in Proposition 1.

Exclusivity yields the highest investment in QoS for A if the effect of a quality increase in q_A on the profits of A is sufficiently small, price discrimination the second highest and no fees the lowest. Exclusivity allows the network operator to capture all gains from QoS increases in A that go to consumers. If the network operator implements price discrimination, there is an extra effect on QoS investment incentives that comes from the fact that increases in the QoS of A allows the network operator to not only raise the price to consumers but also to raise its fee to A. This implies that, if market share is very valuable to A, price discrimination can lead to higher QoS investments than exclusivity. Similarly, the value B places on buying better QoS also gives the network operator higher incentives to invest in QoS as the value to B of buying (compared to not buying) increases. Note also that the network operator will have incentives to improve QoS even if it does not charge content providers, as better QoS will allow it to raise the price consumers pay for access to content providers.[12]

Next, we compare the four different business models the network operator can implement: exclusive access, price discrimination, no fees and no QoS variation. We obtain the following proposition.

Proposition 2: Network operator profits can be ranked as follows:

i) $\Pi^{PD} \geq \Pi^{NF} \geq \Pi^{NQoS}$.

ii) $\Pi^E \geq \Pi^{PD}$, *for* $\underbrace{(P^E - P^{PD})}_{+/-} + \underbrace{(s_E - s_A)}_{+} - s_B - \underbrace{[c(q_A^E) - c(q_A^{PD})]}_{+/-} - c(q_B^{PD}) \geq 0$

iii) Under the linearity assumption the condition in ii) becomes

$$\Pi^E - \Pi^{PD} = -\frac{1}{16ct^2}(8ct^3 + a^2w_A^2 - 3t^2w_A^2 + 2at(w_A^2 - 8ct) + (b+t)^2w_B^2) \geq 0 \tag{6.9}$$

which is increasing in w_A for $t > a$ and in a for $c > \frac{1}{8t^2}(a + t)w_A^2$. It is decreasing in w_B and b.

To see this, note that price to consumers, P, is increasing in both q_A

and q_B ($\partial P/\partial q_A = v'_A(q_A)/2 > 0$ and $\partial P/\partial q_B = v'_B(q_B)/2 > 0$). For Part (i), it is then easy to see that Price Discrimination is better than No Fees ($\Pi^{PD} \geq \Pi^{NF}$) since Price Discrimination both gives the network operator an additional source of revenues (the fees to A and B) and raises profits from consumers since q_A and q_B weakly increase (by Proposition 1). No Fees is also better than No QoS ($\Pi^{NF} \geq \Pi^{NQoS}$) since profits from consumers weakly increase with q_A and q_B (by Proposition 1). Costs of providing QoS also increase but, since the network operator is free to set QoS levels, it could always set them at zero or at the same level in each case. For part ii), we can decompose the difference in profits as follows

$$\Pi^E - \Pi^{PD} = (P^E - P^{PD}) + (s_E - s_A) - s_B - [c(q_A^E) - c(q_A^{PD})] - c(q_B^{PD}). \quad (6.10)$$

The first term is profit change from revenue from consumers, which can increase or decrease. It can also be expressed as

$$(P^E - P^{PD}) = (v_A(q_A^E) - v_A(q_A^{PD})) - (1/2)\,t + (1/2)\,(v_A(q_A^{PD}) - v_B(q_B^{PD})), \quad (6.11)$$

highlighting that it is more likely to be positive if the product differentiation parameter t is small so that A and B are less differentiated in the eyes of consumers, or if the quality difference between A and B is large and QoS of A increases under exclusivity. The second term in equation (10) is positive and is the increase in the fee to A that the network operator can implement since it now sells exclusive access instead of just better QoS. The third term is profit losses from not selling better QoS to B. The fourth term is cost increases from providing a higher level of QoS and the final term is cost savings from not investing in QoS for B. Under linearity, the comparative statics indicate that increasing the difference between the effects of QoS on consumers' valuation of content provider services or the difference between content providers' profitability increases the profitability of excluding one content provider instead of selling access to better QoS.

Hence, exclusive access to consumers will be favored by the network operator if the content providers are viewed as similar by the consumers (t is small); if the difference in quality between A and B is large; if exclusive access is very valuable to A; if A and B are heterogeneous in their ability to profit from consumers; and if cost savings from not improving the QoS of B are large.

Regulatory Regimes

Having established the network operator's preference over different business strategies, QoS improvement choices and pricing decisions, we now

compare regulatory regimes from the point of view of consumers' surplus and total surplus. We assume that the regulator is concerned about total surplus (or total welfare), which we define as the sum of consumer surplus, network operator profits and content provider profits. Network operator profits and content provider profits are given above. Consumer surplus is given by

$$CS = \int_0^x (v_A(q_A) - ty - P)f(y)dy + \int_x^1 (v_B(q_B) - t(1 - y) - P)f(y)dy \tag{6.12}$$

and can be rewritten as

$$CS = v_A(q_A)F(x) + v_B(q_B)(1-F(x)) - t\left(\int_0^x yf(y)dy + \int_x^1 (1-y)f(y)dy\right) - P, \tag{6.13}$$

where the first two terms are utility created from accessing content providers, the next term consumers' transportation costs arising from heterogeneity in consumer preferences, and the final term is the price that consumers pay for access to content providers.[13] For simplicity, we denote consumer surplus as $CS = V - T - P$, the sum of content provider profits from advertising (total profits minus potential fees to the network operator) as $CP = \pi_A(n_A) + \pi_B(n_B)$ and costs of improving QoS by $C = c(q_A) + c(q_B)$. Then, we can denote total welfare under each possible business strategy chosen by the network operator as

$$W^k = V^k - T^k + CP^k - C^k, \tag{6.14}$$

where k denotes the regulatory regime, $k \in \{E, PD, NF, NQoS\}$. This decomposition highlights that any effect on welfare from a particular regime or business strategy affects welfare either though its effect on i) consumers' common valuation of content provider services absent transportation costs, ii) transportation costs (consumers' preference distribution over content), iii) surplus created by content providers due to interaction with consumers and iv) costs of QoS improvements. Given this, we can now state the following proposition.

Proposition 3: Social welfare under the four regimes cannot be unambiguously ranked. The clear private profit rankings of proposition 2 suggest that it may not always be that the social and private incentives are aligned. The socially optimal form of regulation depends on parameter values such that

i) $W^{NF} \geq W^{NQoS}$, *for* $(V^{NF} - V^{NQoS}) - (T^{NF} - T^{NQoS}) + (CP^{NF} - CP^{NQoS}) - C^{NF} \geq 0$.

ii) $W^{PD} \geq W^{NF}$, *for* $(V^{PD} - V^{NF}) - (T^{PD} - T^{NF}) + (CP^{PD} - CP^{NF}) - (C^{PD} - C^{NF}) \geq 0$.

iii) $W^{E} \geq W^{PD}$, *for* $(V^{E} - V^{PD}) - (T^{E} - T^{PD}) + (CP^{E} - CP^{PD}) - (C^{E} - C^{PD}) \geq 0$.

The first term in i)–ii) is positive by assumption 1. The first term in iii) is positive only if QoS offered to A is higher under exclusivity than under price discrimination. The second term is either positive or negative depending on which x minimizes total transportation costs (for example, it is negative if that x is less than (1/2) under assumption 3). The third term is positive by assumption 2 for i)–ii) and may be negative for iii), while the fourth term is always negative. Imposing assumption 3, parts i)–iii) in Proposition 3 reduce to

$$W^{NF} - W^{NQoS} = \frac{(w_A^2 - w_A^2)^2 + 4ct(w_A^2 + w_B^2)}{32c^2t} - \frac{(w_A^2 - w_B^2)^2}{64c^2t} + \frac{(a-b)(w_A - w_B)(w_A + w_B)}{8ct} - \frac{w_A^2 + w_B^2}{16c},$$

$$W^{PD} - W^{NF} = \frac{4act^2w_A^2 + a(a+2t)w_A^4 - 2(-2bct^2 + (bt + a(b+t))w_A^2)w_B^2 + b(b+2t)w_B^4}{32c^2t^3} - \frac{(aw_A^2 - bw_B^2)((a+2t)w_A^2 - (b+2t)w_B^2)}{64c^2t^3} + \frac{(a-b)(aw_A^2 - bw_B^2)}{8ct^2} - \frac{a(a+2t)w_A^2 + b(b+2t)w_B^2}{16ct^2}$$

and

$$W^{E} - W^{PD} = -\frac{4c(a-3t)t^2w_A^2 + (a+t)^2w_A^4 - 2(b+t)(-2ct^2 + (a+t)w_A^2)w_B^2 + (b+t)^2w_B^4}{32c^2t^3} - \frac{48c^2t^4 - ((a+t)w_A^2 - (b+t)w_B^2)^2}{64c^2t^3}$$

$$+\frac{(b-a)-4ct^2+(a+t)w_A^2-(b+t)w_B^2}{8ct^2}$$

$$-\frac{(t-a)(a+3t)w_A^2-(b+t)^2w_B^2}{16ct^2}.$$

Thus, even under assumption 3, the optimal form of regulation depends on parameter values in a non-trivial way. Despite not giving a clear ranking of the regimes, Proposition 3 highlights the four different channels through which total welfare is affected.

POSSIBILITIES FOR FURTHER RESEARCH

There are several possible avenues for further research. First, our main analysis focused entirely on the incentives of the network operator to invest in improving QoS. One may also study content providers' investment incentives. One would expect investment incentives to be lower when the network operator can charge content providers. However, the ability to innovate and offer new services may depend on the level of QoS provided. Some innovations are not possible without a sufficiently high QoS level, which could imply that some content providers' innovation incentives could be higher when the network operator can charge fees to content providers because incentives to improve QoS levels then increase.

Second, our model is very flexible because it allows the network operator to freely invest in supplying capacity and QoS to each content provider separately and to potentially charge separate prices to each content provider. However, such a setup may not be optimal for an analysis of network congestion and prioritization. Our setup can be easily modified in this direction by assuming that QoS levels are dependent on each other, reflecting a situation where the capacity of the network is fixed and congestion occurs. To do this we can generalize the quality of service costs to $c_A(q_A,\mu q_B)$ and $c_B(\mu q_A, q_B)$ with $\partial c_A(q_A,\mu q_B)/\partial q_A > 0$, $\partial c_A(q_A, \mu q_B)/\partial q_B \geq 0$, $\partial c_B(\mu q_A, q_B)/\partial q_A \geq 0$ and $\partial c_B(\mu q_A, q_B)/\partial q_A \geq 0$, where the parameter μ is a measure of network capacity ($\mu = 0$ corresponds to our current case with no relationship between QoS levels). Then, increasing the QoS to A implies that the costs of providing better QoS to B increases because of congestion. An extension along these lines will presumably reduce the overall investment in QoS, but our results are likely to remain unchanged.

Third, an important issue often raised in the context of network neutrality is related to incentives of the network operator to vertically integrate

into the supply of content and to use its position as a network operator to favor its own content. This issue can be analyzed in our framework by considering a merger between A (or B) with the network operator.

Fourth, our analysis is entirely focused on a monopolistic network operator. Introducing competition between network operators could potentially affect the result of the analysis.

Fifth, a crucial part of our analysis is assumption 2, stating that A is more efficient than B in generating revenue from consumers' attention. This assumption is important because it implies that A is more efficient while at the same time consumers value A higher than they value B. An equally plausible situation could involve consumers valuing A higher than B, while A would be less efficient than B in generating revenue from consumers.

CONCLUDING REMARKS

We have compared four different approaches to network neutrality and net management regulation: (i) no variations in QoS and no price discrimination allowed (No QoS variations); (ii) variations in QoS allowed but no price discrimination (No Fees); (iii) variations in QoS and price discrimination allowed but no exclusive contracts allowed between the network operator and a content provider (No Exclusivity); and (iv) no regulation: the network operator can sell exclusive rights to content providers. We found that:

- QoS offered to the two content providers will be highest if the network operator is allowed to price discriminate and charge content providers for access to better QoS. With an exclusive contract, the level of QoS offered may still be higher than with price discrimination if content providers do not profit much from increases in QoS but consumers value QoS highly.
- A private monopolist network operator will always prefer price discrimination to only variations in QoS or to no QoS improvements. The network operator will prefer to implement exclusive contracts if consumers view content providers as similar (low product differentiation) and if there is a large difference in the content providers' ability to profit from consumers so that exclusive access is very valuable for content providers.
- Ranking social welfare to determine optimal regulation yields ambiguous results dependent on parameter values. We identify four channels through which regulation affects total welfare: i) through the effect of QoS variations on consumer common valuation of the content providers, ii) through affecting total transportation

costs determined by consumer preferences over content providers, iii) through redistributing consumers among content providers and thereby changing total surplus created on the content provider side and iv) through changing the total costs of QoS provision.

The policy implication is that we should expect that network operators will have incentives to implement price discrimination and possibly also to exclude some content providers from reaching consumers absent any regulatory intervention. This can be prevented by implementing regulation, but it can come with costs in terms of reducing the network operators' incentives to invest in upgrading their network to achieve better guaranteed Quality of Service. A balanced path, for example as suggested by the FCC NPRM (FCC 2009), may be one way forward as it allows some quality of service variations and investment in improving quality of service that is driven entirely by payments from consumers, but shuns away from allowing investments in quality of service to be driven by payments from content providers as well. It also has the benefit of preventing anti-competitive practices not modeled here, but that could potentially be important for welfare (see e.g. Economides and Tåg (2012) for a discussion).

NOTES

1. See Cerf (2006a, b) for a detailed explanation of the argument that innovation "at the edge" could be reduced.
2. See FCC, Report And Order, In the Matter of Preserving the Open Internet Broadband Industry Practices, GN Docket No. 09-191 & WC Docket No. 07-52, December 21, 2010, at paragraphs 1, 8.
3. See http://gigaom.com/broadband/heres-whats-hiding-behind-verizons-net-neutrality-suit/.
4. See http://www.informationweek.com/news/government/policy/229401316; http://thehill.com/blogs/hillicon-valley/technology/192899-senate-rejects-bid-to-overturn-net-neutrality-rules.
5. http://timwu.org/.
6. This regime is also in line with what was proposed in the "Internet Freedom Preservation Act" introduced to the United States Senate in January 2007. http://thomas.loc.gov/cgi-bin/bdquery/z?d110:S.215: . The summary states "Internet Freedom Preservation Act – Amends the Communications Act of 1934 to establish certain Internet neutrality duties for broadband service providers (providers), including not interfering with, or discriminating against, the ability of any person to use broadband service in a lawful manner. Allows providers to engage in activities in furtherance of certain management and business-related practices, such as protecting network security and offering consumer protection services such as parental controls. Prohibits a provider from requiring a subscriber, as a condition on the purchase of broadband service, to purchase any cable service, telecommunications service, or IP-enabled voice service. Requires a report from the Federal Communications Commission (FCC) to specified congressional committees on provider delivery of broadband content, applications, and services."
7. http://hraunfoss.fcc.gov/edocs_public/attachmatch/FCC-05-151A1.pdf.

8. Note that the explicit timing in stage 2 and 3 does not matter. The time structure is chosen for expositional purposes.
9. That the market is covered is essentially an assumption on that $v_A(q)$ and $v_B(q)$ are sufficiently large.
10. The ISP can always choose to sell exclusive access to B instead of to A, in which case A's profits are zero.
11. For second order conditions to hold, we impose $v_A'' - c'' \leq 0$, $(1/2)v_A'' + \pi_A'' - c'' \leq 0$, $(1/2)v_B'' + \pi_B'' - c'' \leq 0$, $(1/2)v_A'' - c'' \leq 0$ and $(1/2)v_B'' - c'' \leq 0$.
12. Comparing the case of exclusivity to the case of no fees, note that an increase in q_A under exclusivity implies that the network access price P can be increased more than under the no fees case. The reason is that under exclusivity QoS changes do not affect transportation costs since P is set by assumption such that they are always t for the marginal consumer (to ensure that the market remains covered).
13. Note that as we consider only the situation of a covered market, there are no welfare effects of changing the price for Internet access. Thus, we get no effect on welfare from monopoly pricing by the ISP.

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