The Effect of Paid Peering Fees on Broadband Prices and Consumer Surplus

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Abstract

Internet users have suffered collateral damage in tussles over paid peering between large ISPs and large content providers. The issue will arise again when the FCC considers a new net neutrality order. In this paper, we model the effect of paid peering fees on broadband prices and consumer surplus.

We first consider the effect of paid peering on broadband prices. ISPs assert that paid peering revenue is offset by lower broadband prices, and that ISP profits remain unchanged. Content providers assert that paid peering fees do not result in lower broadband prices, but simply increase ISP profits.

We adopt a two-sided market model in which an ISP maximizes profit by setting broadband prices and a paid peering price. To separately evaluate the effect on consumers who utilize video streaming and on consumers who don't, we model two broadband plans: a basic plan for consumers whose utility principally derives from email and web browsing, and a premium plan for consumers with significant incremental utility from video streaming.

Our result shows that the claims of the ISPs and of the content providers are both incorrect. Paid peering fees reduce the premium plan price; however, the ISP passes on to its customers only a portion of the revenue from paid peering. We find that ISP profit increases but video streaming profit decreases as an ISP moves from settlement-free peering to paid peering price.

We next consider the effect of paid peering on consumer surplus. ISPs assert that paid peering increases consumer surplus because it eliminates an inherent subsidy of consumers with high video streaming use by consumers without. Content providers assert that paid peering decreases consumer surplus because paid peering fees are passed onto consumers through higher video streaming prices and because there is no corresponding reduction in broadband prices.

We simulate a regulated market in which a regulatory agency determines the maximum paid peering fee (if any) to maximize consumer surplus, an ISP sets its broadband prices to maximize profit, and a content provider sets its video streaming price. Simulation parameters are chosen to reflect typical broadband prices, video streaming prices, ISP rate of return, and content provider rate of return.

We find that consumer surplus is a uni-modal function of the paid peering fee. The paid peering fee that maximizes consumer surplus depends on elasticities of demand for broadband and for video streaming. However, consumer surplus is maximized when paid peering fees are significantly lower than those that maximize ISP profit. However, it does not follow that settlement-free peering is always the policy that maximizes consumer surplus. The direct peering price depends critically on the incremental ISP cost per video streaming subscriber; at different costs, it can be negative, zero, or positive.

Keywords:
Broadband, Regulation, Net Neutrality, Two-sided Model, Interconnection, Paid Peering

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1. Introduction

It is no longer clear who should pay whom and how much for interconnection between Internet Service Providers (ISPs) and content providers. Large ISPs claim that large content providers are imposing a cost on ISPs by sending large amounts of traffic to their customers. ISPs claim that it is more fair that content providers pay for this cost than consumers, because then this cost will be paid only by those consumers with high usage. In contrast, large content providers (including CDNs) claim that when they interconnect with ISPs at interconnection points (IXPs) close to consumers, they are already covering the costs of carrying traffic through the core network, and that consumers are already covering the costs of carrying traffic through the ISP's access network. These disputes between large ISPs and large content providers have recurred often during the last 10 years. When not resolved, large ISPs have often refused to increase capacity at interconnection points with large content providers and transit providers, resulting in sustained congestion which has degraded users' quality of experience because of reduced throughput, increased packet loss, increased delay, and increased jitter.

As a result, there have been an increasing number of disputes over interconnection between large ISPs, on one side, and large content providers and transit providers, on the other side. In 2013-2014, a dispute between Comcast and Netflix over terms of interconnection went unresolved for a substantial period of time, resulting in interconnection capacity that was unable to accommodate the increasing Netflix video traffic. In 2014, Netflix and a few transit providers brought the issue to the attention of the United States Federal Communications Commission (FCC), which was writing updated net neutrality regulations. The FCC discussed the dispute in the 2015 Open Internet Order (Federal Communications Commission, 2015).

The FCC first summarized the arguments of large content providers and transit providers. It noted that "[content] providers argue that they are covering the costs of carrying [their]

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traffic through the network, bringing it to the gateway of the Internet access service". Large content providers and transit providers argued that they should be entitled to settlement-free peering if the interconnection point is sufficiently close to consumers. The lack of willingness of large ISPs to offer settlement-free peering peering with large content providers, and to augment the capacity of existing interconnection points with transit providers with which they had settlement-free peering agreements, had led to the impasse. The FCC noted that "[s]ome [content] and transit providers assert that large [ISPs] are creating artificial congestion by refusing to upgrade interconnection capacity ... for settlement-free peers or CDNs, thus forcing [content] providers and CDNs to agree to paid peering arrangements."

The FCC then summarized the arguments of large ISPs. It noted that "large broadband Internet access service providers assert that [content] providers such as Netflix are imposing a cost on broadband Internet access service providers who must constantly upgrade infrastructure to keep up with the demand". The large ISPs explained that the network upgrades include adding capacity in the middle mile and access networks. The FCC noted that the large ISPs asserted that if they absorb these costs, then the ISPs would recoup these costs by increasing the prices for all subscribers, and that the large ISPs argued that "this is unfair to subscribers who do not use the services, like Netflix, that are driving the need for additional capacity".

Both large ISPs and large content providers agree that settlement-free peering is appropriate when both side perceive equal value to the relationship. However, whereas large content providers assert that carrying their traffic to an interconnection point close to consumers is of value, large ISPs assert that "if the other party is only sending traffic, it is not contributing something of value to the broadband Internet access service provider".

In 2015, the FCC was concerned about the duration of unresolved interconnection disputes and about the impact of these disputes upon consumers. However, it concluded that in 2015 it was "premature to draw policy conclusions concerning new paid Internet traffic exchange arrangements between broadband Internet access service providers and [content] providers, CDNs, or backbone services." Thus, in 2015 the FCC adopted a case-by-case approach in which it would monitor interconnection arrangements, hear disputes, and ensure that ISPs are not engaging in unjust or unreasonable practices. However, in 2018, the FCC reversed itself and ended its oversight of interconnection arrangement, when it repealed most of the 2015 net neutrality regulations (Federal Communications Commission, 2018). It is almost certain that the FCC will revisit the issue in the next few years.

The goal of this paper is to evaluate the effect of paid peering fees on broadband prices and consumer surplus. Our principal approach is to model the interaction between an ISP and its subscribers, and between an ISP and large content provider, as a two-sided market model. We then consider the impact of an ISP determined paid peering fee on both consumers and content providers. Finally, we consider what level of peering fee would maximize consumer surplus. To the best of our knowledge, this is the first work to use a two sided market model to analyze the effect of paid peering fees on broadband prices and consumer surplus.

The rest of this paper is organized as follows. Section 2 summarizes the relevant research literature. Although two-sided market models have been widely used to examine issues relating to net neutrality or to other aspects of various telecommunication markets, there are few that examine the effects of interconnection agreements.

Section 3 proposes a model of user subscription to broadband service tiers and to video streaming. We consider a monopoly ISP that offers basic and premium tiers differentiated by bandwidth and price. We aggregate all video streaming providers that directly interconnect with the ISP. Consumers differ in the utilities they place on broadband service tiers and on video streaming, and each customer chooses the service which maximize his/her surplus. We derive the demand of each broadband service tier and of video streaming services. We also derive the and associated consumer surplus, ISP profit, and aggregated video service provider profit.

To focus on the effect of direct peering fees, in Section 4 we propose a two-sided model in which a monopoly ISP maximizes its profit by choosing broadband prices as well as a direct peering price. An ISP earns revenue by increasing its direct peering price, but this will also trigger a decrease in the demand for the ISP's premium tier. An ISP also earns revenue by increasing its premium tier price, but this will also trigger a decrease in demand for video streaming and thus in the revenue from direct peering. We derive numerical model parameters based on public data about broadband and video streaming prices and subscription.

In Section 5, we consider the effect of paid peering on broadband prices as well as ISP profit. ISPs assert that paid peering revenue is offset by lower broadband prices, and that ISP profits remain unchanged. Content providers assert that direct peering prices do not result in lower broadband prices, but simply increase ISP profits. Using our model, we find that the basic tier price is almost unaffected by direct peering fees, but that the premium tier price is lower when an ISP chooses the direct peering price to maximize profit than when settlement-free peering is used. Also, we find that positive direct peering prices result in increased ISP profit and in decreased video streaming profit.

In Section 6, we consider the impact of paid peering on consumer surplus. ISPs assert that paid peering fees increase aggregate consumer surplus because they eliminate an inherent subsidy of consumers with high video streaming use by consumers without such use. However, content providers assert that paid peering fees decrease consumer surplus because they are passed onto consumers through higher video streaming prices without a corresponding reduction in broadband prices. To address this question, we consider the direct peering price to be an independent variable set by a regulator with the goal of maximizing consumer surplus. We show that consumer surplus is a uni-modal function of the direct peering price, and that the direct peering price that maximizes consumer surplus is substantially less than the direct peering price that maximizes ISP profit and less than the incremental ISP cost per video streaming subscriber. In Section 7, we show that the direct peering price depends critically on this cost, and that at different costs it can be negative, zero, or positive.

2. Research Literature

A few papers examine the effects of interconnection agreements in the Internet backbone by using two-sided market model.

Kim (2020) is concerned with whether an ISP that is vertically integrated with a content provider may use direct peering fees to gain advantages over unaffiliated content providers. It proposes a two-sided market model with one monopoly ISP, one affiliated content provider, and one unaffiliated content provider. The ISP is assumed to provide direct interconnection with its affiliated content provider for free, but can choose a direct peering price to charge the unaffiliated content provider. The two-sided model also incorporates indirect interconnection between the unaffiliated content provider and the ISP through a transit provider. The paper finds that, when the cost of direct interconnection is low, the ISP sets the direct peering price at the maximum amount that the unaffiliated content provider is willing to pay, so that its earns the maximum possible revenue from direct interconnection. However, when the cost of direct interconnection is high, the ISP sets the direct peering price above the maximum amount that the unaffiliated content provider is willing to pay, so that the affiliated content provider has an advantage over the unaffiliated content provider. This outcome suggests that a vertically integrated ISP might exert leverage through direct interconnection in order to favor its affiliated content provider. They find consumer welfare may or may not be maximized by direct interconnection; however, this conclusion is strongly dependent on the two-sided model. The research problem addressed in Kim (2020) differs from that we consider here. First, Kim (2020) is focused on the effect of a direct peering price on competition between content providers, while we focus on the effect on both content providers and consumers. Second, Kim (2020) adopts a game theoretic approach, while we consider both profit maximization and consumer surplus maximization.

Laffont et al. (2003) is concerned with how interconnection fees between a pair of ISPs affects the allocation of network costs between consumers and content providers. It considers a two-sided model in which there is perfect competition between two ISPs, each of which can serve any customer or content provider. The model assumes that interconnection fees are symmetric between the two ISPs, but that this fee affects each ISP's market shares of consumers and of content providers. The paper finds that if an ISP has market power, then the direct peering price depends not only on elasticities of demand and network externalities, but also on the ISP's relative market power. Furthermore, the ISP-chosen direct peering price does not maximizes consumer surplus. Although there are some parallels between the results of Laffont et al. (2003) and the results of our paper, the issues and models are quite different, since Laffont et al. (2003) is concerned with interconnection fees between two competitive ISPs whereas we are concerned with interconnection fees between a monopoly ISP and content providers.

Wang et al. (2018) is concerned with how interconnection fees between an ISP and content providers affects ISP profit and consumer surplus. It proposes a two-sided model in which a monopoly ISP may provide content providers the choice between paid peering and settlement-free peering and in which the ISP charges consumers an amount proportional to their monthly usage. The ISP is assumed to choose both the direct peering price and the consumer per-unit usage price. The paper finds that when the ISP maximizes profit, it always offers paid peering, and it may or may not also offer settlement-free peering. In contrast, when prices are set to maximize consumer surplus, the ISP always offers settlement-free peering, and it may or may not also offer paid peering. Although both Wang et al. (2018)

and our paper are concerned with the impact of interconnection fees on both ISP profit and consumer surplus, Wang et al. (2018) is focused primarily on the ISP decision of how much capacity to allocate to paid versus settlement-free peering, whereas we are focused primarily on the ISP decision of the direct peering price.

3. A Model of User Subscription to Broadband and to Video Streaming

Before we can analyze the the effect of paid peering on broadband prices, we need a model of user subscription to broadband service tiers and to video streaming.

3.1. Service offerings

ISPs offer multiple tiers of broadband services, differentiated principally by download speed. ISPs typically market these broadband service tiers by recommending specific tiers to consumers who engage in specific types of online activities. For example, Comcast recommends a lower service tier to consumers who principally use their Internet connection for email and web browsing, but a higher service tier to consumers who use the Internet for video streaming. Much of the debate over paid peering concerns consumers who stream large volumes of video. Thus, we construct here a model that includes two broadband service tiers: a basic tier with a download speed intended for email, web browsing, and a limited amount of video streaming; and a premium tier (at a higher price) with a download speed intended for a substantial amount of video streaming. Although most often offer more then two tiers, the majority of customers subscribe to a subset of two tiers, and this two tier model is sufficient to separately evaluate the effect of paid peering prices on consumers who utilize video streaming and on consumers who don't.

Specifically, we model a single monopoly ISP that offers a basic tier at a monthly price P^b and a premium tier at a monthly price $P^b + P^p$. We consider N consumers, each of whom may subscribe to the basic tier, the premium tier, or neither. We denote user i's utility per month from subscription to the basic tier by b_i, and user i's utility per month from subscription to the premium tier by $b_i + p_i$. We presume that a consumer who gains significant utility from video streaming subscribes to the premium tier.

To analyze the effect of paid peering prices on broadband prices, we focus on the aggregate of all video streaming providers that directly interconnect with the ISP and that may pay (or be paid) a fee for peering with the ISP. We model the aggregate of all plans offered by these video streaming providers, but to keep the model tractable we consider a single price of P^v per month for the aggregate. We denote user i's utility per month from subscription to video streaming providers by v_i. Consumer i's utility from all other content is included in $b_i + p_i$.

Consumers differ in the utilities they place on broadband service tiers and on video streaming. We assume that the number of consumers N is large, and we denote the joint probability density function of their utilities by $f_{B,P,V}(b, p, v)$.

3.2. Demand functions

Each consumer thus has four choices

$$X_i \triangleq \begin{cases} n, & \text{do not subscribe} \\ b, & \text{subscribe to the basic tier} \\ p, & \text{subscribe to the premium tier but not to a video streaming provider} \\ v, & \text{subscribe to the premium tier and to a video streaming provider.} \end{cases} \quad (1)$$

Consumer i's consumer surplus, defined as utility minus cost, under each choice is thus

$$CS_i(X_i) = \begin{cases} 0, & X_i = n \\ b_i - P^b, & X_i = b \\ b_i + p_i - P^b - P^p, & X_i = p \\ b_i + p_i + v_i - P^b - P^p - P^v, & X_i = v. \end{cases} \quad (2)$$

Each consumer is assumed to maximize consumer surplus. Thus, consumer i adopts the choice

$$X_i^* \triangleq \arg\max_{X_i} CS_i(X_i), \quad (3)$$

and earns a corresponding consumer surplus $CS_i^* \triangleq CS_i(X_i^*)$.

Each of the N consumers makes an individual choice per (3). The consumers who choose to subscribe to the basic tier are those whose utility b_i from subscription to the basic tier exceeds its monthly price P^b, whose incremental utility p_i from subscription to the premium tier without subscribing to a video streaming provider falls below the incremental monthly price P^p, and whose incremental utility $p_i + v_i$ from subscription to the premium tier and to video streaming falls below the corresponding incremental monthly price $P^p + P^v$. Thus, the demand[3] for the basic tier is given by

$$N^b(P^b, P^p, P^v) = N \int_{-\infty}^{P^p} \int_{-\infty}^{P^p+P^v-p} \int_{P^b}^{\infty} f_{B,P,V}(b, p, v)\, db\, dv\, dp. \quad (4)$$

Similarly, the consumers who choose to subscribe to the premium tier but not to video streaming are those whose utility $b_i + p_i$ from subscription to the premium tier exceeds its monthly price $P^b + P^p$, whose incremental utility p_i from subscription to the premium tier without subscribing to video streaming exceeds the incremental monthly price P^p, and whose incremental utility v_i from subscription to video falls below the incremental monthly price P^v. Thus, the number of consumers who subscribe to the premium tier but who do not subscribe to video streaming is given by

$$N^p(P^b, P^p, P^v) = N \int_{-\infty}^{P^v} \int_{P^p}^{\infty} \int_{P^b+P^p-p}^{\infty} f_{B,P,V}(b, p, v)\, db\, dp\, dv. \quad (5)$$

[3]Since we model a finite number N of consumers whose utilities are given by a joint probability density function, this equation, and other similar equations below, give the *average demand*. However, for simplicity of presentation, we use the term *demand*.

Finally, the consumers who choose to subscribe to both the premium tier and video streaming are those whose utility $b_i + p_i + v_i$ from subscription to both services exceeds the combined cost $P^b + P^p + P^v$, whose incremental utility $p_i + v_i$ from subscription to only the basic tier exceeds the corresponding incremental price $P^p + P^v$, and whose incremental utility v_i from subscription to video streaming falls exceeds the incremental monthly price P^v. Thus, the demand for video streaming is given by

$$N^v(P^b, P^p, P^v) = N \int_{P^v}^{\infty} \int_{P^p+P^v-v}^{\infty} \int_{P^b+P^p+P^v-p-v}^{\infty} f_{B,P,V}(b, p, v)\; db\; dp\; dv. \tag{6}$$

The demand for the premium tier is $N^p + N^v$, the sum of the demands for the premium tier without and with a subscription to the streaming video provider.

3.3. Consumer surplus

The aggregate consumer surplus will be an important quantity to consider in our deliberations below. It can be easily determined for each set of consumers using the number of subscribers in each set (4-6) and the surplus of each consumer (2). Given a set of prices, the aggregate consumer surplus of subscribers to the basic tier is

$$CS^b(P^b, P^p, P^v) = N \int_{-\infty}^{P^p} \int_{-\infty}^{P^p+P^v-p} \int_{P^b}^{\infty} (b - P^b) f_{B,P,V}(b, p, v)\; db\; dv\; dp. \tag{7}$$

Similarly, the aggregate consumer surplus of consumers who subscribe to the premium tier but not to video streaming is

$$CS^p(P^b, P^p, P^v) = N \int_{-\infty}^{P^v} \int_{P^p}^{\infty} \int_{P^b+P^p-p}^{\infty} (b + p - P^b - P^p) f_{B,P,V}(b, p, v)\; db\; dp\; dv, \tag{8}$$

and the aggregate consumer surplus of consumers who subscribe to both the premium tier and video steaming is

$$CS^v(P^b, P^p, P^v) = N \int_{P^v}^{\infty} \int_{P^p+P^v-v}^{\infty} \int_{P^b+P^p+P^v-p-v}^{\infty} (b+p+v-P^b-P^p-P^v) f_{B,P,V}(b, p, v)\; db\; dp\; dv. \tag{9}$$

The aggregate consumer surplus over all consumers is defined as

$$CS(P^b, P^p, P^v) \triangleq CS^b(P^b, P^p, P^v) + CS^p(P^b, P^p, P^v) + CS^v(P^b, P^p, P^v) \tag{10}$$

3.4. Profits

We assume that the ISP incurs a monthly marginal cost C^b per basic tier subscriber. The ISP marginal profit per basic tier subscriber is thus $P^b - C^b$. We assume that the ISP incurs a monthly marginal cost $C^b + C^p$ per premium tier subscriber who does not also subscribe to video streaming. The ISP marginal profit per such broadband service tier subscriber is thus $P^b + P^p - C^b - C^p$.

The marginal cost to an ISP associated with video streaming is at the core of the debate over paid peering, and thus we must be careful in its formulation. Here, we have assumed that only premium tier subscribers engage in a substantial amount of video streaming, consistent with ISP marketing of their service tiers. We have further divided premium tier subscribers according to whether they also subscribe to video streaming services that have direct interconnection with the ISP.

For generality, we thus associate an ISP monthly marginal cost $C^b + C^P + C^d$ per video streaming subscriber, where the d denotes direct interconnection. The incremental ISP cost C^d per video streaming subscriber may be negative, zero, or positive. It is critical to note that this incremental cost is not that of the interconnection point itself between the ISP and each video streaming provider, as the cost of the interconnection point itself is negligible. However, there are several variables that may affect the incremental ISP cost per video streaming subscriber. First, video streaming subscribers receive substantially more traffic per month than premium tier subscribers who don't subscribe to video streaming. Second, when a content provider switches from indirect interconnection through a transit provider to an ISP to direct interconnection with the ISP, the location of the interconnection point may change. This change in the location of the interconnection point may result in either shorter or longer paths on the ISP's network from the interconnection point to the subscriber, and thus either a lower or higher incremental ISP cost per video streaming subscriber.

We also consider a direct peering price of P^d per video streaming subscriber for direct interconnection between the ISP and video streaming providers. This price may be positive if the ISP charges video streaming providers for direct interconnection, negative if the video streaming providers charge the ISP for direct interconnection, or zero if the peering is settlement-free.

The ISP marginal profit per video streaming subscriber is $P^b + P^p + P^d - C^b - C^p - C^d$. The total ISP profit (excluding fixed costs)[4] is thus

$$\pi^{ISP}(P^b, P^p, P^d, P^v) = (P^b - C^b)N^b + (P^b + P^p - C^b - C^p)N^p + (P^b + P^p + P^d - C^b - C^p - C^d)N^v. \tag{11}$$

We assume that the video streaming providers incur a monthly marginal cost C^v per subscriber. The aggregate video streaming provider marginal profit per subscriber is thus $P^v - C^v - P^d$, and their total profit (excluding fixed costs)[5] is

$$\pi^{VSP}(P^b, P^p, P^d, P^v) = (P^v - C^v - P^d)N^v. \tag{12}$$

4. A Two-Sided Model for ISP Profit Maximization

The previous section presented a model for consumer demand for broadband and video streaming, resulting in the demand functions (4-6), the corresponding aggregate consumer surplus (7-9), and the corresponding ISP and video streaming provider profits (11-12). In this section, we formulate a two-sided model of how the prices are determined.

[4]Throughout the paper, ISP profit excludes fixed costs.

[5]Throughout the paper, aggregate video streaming profit excludes fixed costs.

4.1. Analytical model

There are a number of options for modeling how the broadband service tier prices (P^b and P^p), the video streaming price (P^v), and the direct peering price (P^d) are determined.

Throughout the paper, we presume that the ISP has no significant competition for broadband service at acceptable speeds within the footprint of its service territory. Thus, we assume that the ISP determines its broadband service tier prices (P^b and P^p) to maximize its profit.

A key question, critical to this analysis, is how the direct peering price (P^d) is determined. Once a subscriber chooses an ISP, the ISP has a monopoly on the transport of traffic within the ISP's access network that the customer resides in. In contrast, there may be a competitive market for transport of Internet traffic across core networks. In this section, we assume that the location of direct interconnection between the ISP and each video streaming provider is close enough to the consumers so that all of the transport from the interconnection point to the consumers falls within the ISP's access network. Correspondingly, we assume that the ISP has market power to determine the direct peering price (P^d) and that it sets this price to maximize its profit.

The ISP thus chooses the broadband service tier prices (P^b and P^p) and the direct peering price (P^d) to maximize its profit, namely

$$(P^b_{ISP}, P^p_{ISP}, P^d_{ISP}) = \arg \max_{(P^b, P^v, P^d)} \pi^{ISP}(P^b, P^p, P^d, P^v) \tag{13}$$

In contrast, we assume that there is perfect competition between the video streaming providers, and that this market determines an equilibrium rate of return r^{VSP}_{min} for the video streaming providers. Hence, we assume that the video streaming providers do not independently determine their aggregate price P^v.

Finally, one remaining key question is whether the video streaming providers can pass through any direct peering price (P^d) to their customers by adding it to the aggregate video streaming price (P^v). We presume that an ISP charging direct peering prices would likely charge them to both directly interconnected content providers and directly interconnected transit providers. We further presume that transit providers would pass direct peering prices through to their customers. As a consequence, we foresee that direct peering prices would be paid by all large video service providers selling to the ISP's customers. One could incorporate these direct peering prices into the rate of return (r^{VSP}_{min}), but we find it useful to keep the direct peering price separate from the rate of return:

$$P^v(P^d) = (r^{VSP}_{min} + 1)C^v + P^d \tag{14}$$

Equations (13-14) set up a two-sided model in which the ISP earns revenue from both from its customers and video service providers (if $P^d > 0$). The combination of the two equations captures the inter-dependencies between the ISP, the video services providers, and the consumers. The ISP-determined direct peering price (P^d), along with the market-determined video services rate of return (r^{VSP}_{min}), leads to an aggregate video streaming price (P^v). The ISP-determined broadband service tier prices (P^b and P^p), along with the aggregate video streaming price (P^v), leads to demands for each broadband service tier (N^b and $N^p + N^v$) and for video streaming services (N^v). These demands in turn affect how the ISP sets each of the prices.

Since the aggregate video service price (P^v) is solely determined by (14), we can represent the ISP's profit as a function of three variables rather than four:

$$(P^b_{ISP}, P^p_{ISP}, P^d_{ISP}) = \arg \max_{(P^b, P^v, P^d)} \pi^{ISP}(P^b, P^p, P^d, (r^{VSP}_{min} + 1)C^v + P^d) \tag{15}$$

4.2. Numerical parameters

This two-sided model is somewhat amenable to closed-form analysis. However, we find it useful to also examine the model under a set of realistically chosen parameters. We set out those parameters in this subsection.

The joint probability density function of user utilities for the basic tier, the premium tier, and video streaming is represented by $f_{B,P,V}(b, p, v)$. For numerical evaluation, we assume that each utility is independent and has a Normal distribution: $B \sim \mathcal{N}(\mu_b, \sigma_b^2), P \sim \mathcal{N}(\mu_p, \sigma_p^2), V \sim \mathcal{N}(\mu_v, \sigma_v^2)$. We need to determine numerical values for the means and variances.

The ISP incurs a monthly marginal cost of C^b per subscriber, a monthly marginal cost of C^p per premium tier subscriber, and an incremental ISP cost C^d per video streaming subscriber. We need to determine numerical values for these three costs.

Unfortunately, direct information about user utilities and ISP costs is scarce. Instead, we choose numerical values for user utilities and ISP costs indirectly using available information about demand and prices.

There are several sets of publicly available statistics about broadband prices and subscriptions (Pew Research Center, 2021; The Wall Street Journal, 2019). While the set of statistics differ, they show that roughly 75% of households in the United States subscribe to fixed broadband service. Hence, we wish to choose numerical values for user utilities and ISP costs so that, at the ISP profit maximizing prices, $(N^b + N^p + N^v)/N = 0.75$. For each ISP, the statistics show that subscribers predominately choose among two service tiers, which we map to the basic and premium tiers modeled above, with roughly 2/3 of subscribers choosing the premium tier. Hence, we wish to choose numerical values for user utilities and ISP costs so that, at the ISP profit maximizing prices, $N^b/N = (0.75)(1/3) = 0.25$ and $(N^p + N^v)/N = (0.75)(2/3) = 0.50$. Moreover, the statistics also reveal that the price of the lower of the two popular tiers is roughly \$50 per month, and the price of higher of the two popular tiers is roughly \$70 per month. Hence, we wish to choose numerical values for user utilities and ISP costs so that the ISP profit maximizing prices are $P^b = \$50.00$ and $P^p = \$20.00$.

There are also several sets of publicly available statistics about video streaming prices and subscriptions (Leichtman Research Group, 2020; Parks Associates, 2020). While the set of statistics differ, they show that roughly 75% of households in the United States that subscribe to fixed broadband service also subscribe to at least one video streaming service. Hence, we wish to choose numerical values for user utilities and ISP costs so that, at the ISP profit maximizing prices, $N^v/N = (0.75)(0.75) \approx 0.56$.

There is even less information about the variance of user utilities, or correspondingly about the elasticity of demand. We choose $\sigma_b = \mu_b/4$, $\sigma_p = \mu_p/4$, and $\sigma_v = \mu_v/4$, which results in reasonably wide distributions.[6]

From these statistics we can generate targets for the the ISP profit maximizing broadband prices P^b and P^p, and for the demands N^b, N^p, and N^v at these prices. We cannot, however, use these statistics to generate a target for the ISP profit maximizing direct peering fee P^d, since information about these fees is scarce. Instead, we estimate the incremental ISP cost C^d per video streaming subscriber. There are some statistics about the monthly usage of various sets of broadband subscribers. None of these are detailed enough to accurately estimate the monthly usage from video streaming. We use a very rough estimate of 400 GB per month of aggregate usage per subscriber, including 300 GB per month of aggregate video streaming per video streaming subscriber. We need to translate this estimate of usage to an estimate of ISP cost. Unfortunately, we know very little about ISP network costs. At a price of \$70/month for 400 GB, the average cost is \$0.175/GB. However, the marginal cost is much lower than the average cost, due to high fixed costs. Here we use \$0.01/GB, but we acknowledge this could be far off from the real value. Combining these two estimates, we obtain a target of $C^d = \$3.00$ per month per video subscriber. That said, later in this paper, we will consider a wide range of values of C^d.

This now gives us six target values (P^b, P^p, N^b, N^p, N^v, and C^d) to determine the six desired parameters (μ_b, μ_p, μ_v, C^b, C^p, and P^d). We can use the three equations for demand (4-6) and the ISP profit maximization equation (15) to determine these six desired parameters. The result is: $\mu_b \approx \$56.12$, $\mu_p \approx \$18.91$, $\mu_v \approx \$27.67$, $C^b \approx \$16.50$, $C^p \approx \$19.00$, and $P^d \approx \$4.59$. In addition, we use an equilibrium rate of return for the video streaming providers of $r^{VSP}_{min} = 13.6\%$.

We use these parameters in the remainder of the paper except as noted.

5. The Effect of Paid Peering on Prices

We now consider the effect of paid peering on broadband prices. ISPs assert that paid peering revenue is offset by lower broadband prices, and that ISP profits remain unchanged. Content providers assert that direct peering prices do not result in lower broadband prices, but simply increase ISP profits. The goal is this section is to evaluate these assertions.

With an understanding of how the ISP sets the prices $(P^b_{ISP}, P^p_{ISP}, P^d_{ISP})$, we can now evaluate the impact of the direct peering price P^d upon the broadband prices P^b and P^p.

As we did in the previous section, we assume that the video streaming price P^v is set by (14) so that the video streaming providers earn a specified rate of return r^{VSP}_{min}. However, whereas in (15) the ISP sets the direct peering price P^d to maximize profit, in this section we make the direct peering price P^d an independent variable so that we can judge its impact on other prices.

[6]The results below are not very sensitive to these choices.

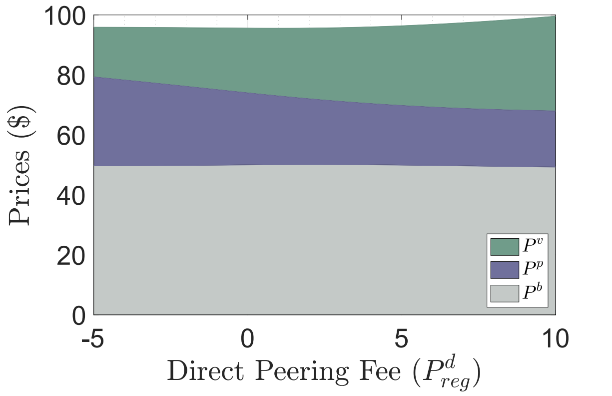


Figure 1: Effect of Direct Peering Fee on Broadband Prices and the Aggregate Video Streaming Price

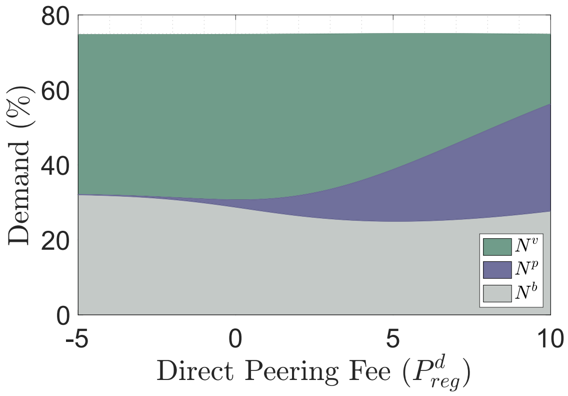


Figure 2: Effect of Direct Peering Fee on Demand (Percentage to Total)

Given a specified direct peering price P^d_{reg}, the ISP is assumed to choose the tier prices P^b and P^p so as to maximize profit, namely

$$(P^b_{reg}, P^p_{reg}) = \arg \max_{(P^b, P^p)} \pi^{ISP}(P^b, P^p, P^d_{reg}, (r^{VSP}_{min} + 1)C^v + P^d_{reg}). \tag{16}$$

The ISP chosen prices (P^b_{reg}, P^p_{reg}) are a function of the independently set price P^d_{reg}. The video streaming price P^v is also a function of P^d_{reg}. Figure 1 shows the prices of both broadband tiers and the aggregate video streaming price as a function of the independently chosen direct peering fee P^d_{reg}.

We initially compare prices and profits in the case in which the ISP chooses the direct peering price to maximize profit ($P^d = \$4.59$) to the case in which settlement-free peering is used (i.e., $P^d = \$0$). We start at the profit-maximizing direct peering price $P^d = \$4.59$ and consider a small decrease. If the ISP did not change the prices for the broadband tiers (which it will), then a small decrease in the direct peering price would result in a small decrease in demand for the basic tier, a small decrease in demand for the premium tier without video streaming, and a small increase in demand for the premium tier with video streaming.

However, the ISP now has the motivation to modify the broadband tier prices. The decrease in the direct peering price results in a decrease in the aggregate price of video streaming. As a consequence, the ISP will recoup most of the decreased direct peering price by increasing the incremental price for the premium tier P^p. It does not, however, change the basic tier price P^b by much at all, since increasing the premium tier price results in some users downgrading to the basic tier, which more than offsets those who would otherwise upgrade from the basic tier to the premium tier to take advantage of lower video streaming prices. The signs of these trade-offs remain the same in the entire range from $P^d = \$4.59$ to $P^d = \$0$.

Figure 2 shows the corresponding demands for each broadband tier and for video streaming. Again, we start at the profit-maximizing direct peering price $P^d = \$4.59$ and consider a small decrease. The ISP's increase in the premium tier price drives some consumers who subscribe to the premium tier but not to video streaming to downgrade to the basic tier.

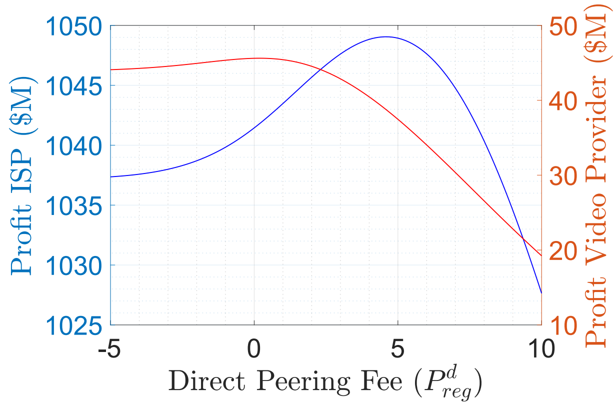


Figure 3: Effect of Direct Peering Fee on Profit of ISP and Video Streaming Provider

However, the total price for the premium tier and video streaming, $P^b + P^p + P^v$, decreases, and thus some consumers who subscribe to the premium tier but not to video streaming now choose to start subscribing to video streaming.

Figure 3 shows the corresponding ISP profit and aggregate video streaming provider profit. The ISP's profit from the video streaming subscribers increases because the demand N^v increases and the price per subscriber $P^b + P^p$ increases. The ISP's profit from premium tier subscribers without video streaming decreases, because the demand N^p decreases more than the price P^b+P^p increases. Finally, the ISP's profit from basic tier subscribers increases, because the demand N^b increases while the price P^b remains virtually unchanged.

We can now evaluate the stakeholder claims about the effect of paid peering on broadband prices and ISP profits. Recall that ISPs assert that paid peering revenue is offset by lower broadband prices, whereas content providers assert that direct peering prices do not result in lower broadband prices. We find that the basic tier price P^b is almost the same in the case in which the ISP chooses the direct peering price to maximize profit ($P^d = \$4.59$) as in the case in which settlement-free peering is used ($P^d = \$0$). We also find that the premium tier price $P^b + P^p$ decreases by \$3.98 (from \$73.98 to \$70.00) if we change from settlement-free peering ($P^d = \$0$) to paid peering ($P^d = \$4.59$), but the aggregate video streaming price increases by \$4.60 (from \$21.59 to \$26.19). Thus, to the extent that ISPs assert that paid peering reduces the price of the basic tier, we disagree. Paid peering should be expected to reduce the price of the premium tier, but this reduction in broadband price is more than offset by an increase in video streaming prices.

Recall that ISPs assert that their profits are unaffected by direct peering fees, whereas content providers assert that direct peering fees increase ISP profits. We find that the ISP profit increases by 0.8% if we change from settlement-free peering ($P^d = \$0$) to paid peering ($P^d = \$4.59$). However, the larger effect is on aggregate video streaming profit, which decreases by 18%.

6. The Effect of Paid Peering on Aggregate Consumer Surplus

In the previous section, we analyzed the effect of paid peering on broadband prices. In this section, we turn to the impact of paid peering on consumer surplus. ISPs assert that paid peering fees increase aggregate consumer surplus because they eliminate an inherent subsidy of consumers with high video streaming use by consumers without such use. Content providers assert that paid peering fees decrease aggregate consumer surplus because they are passed onto consumers through higher video streaming prices without a corresponding reduction in broadband prices.

A portion of these assertions was addressed in the previous section. We now know that when an ISP sets direct peering prices so as to maximize profit, it sets those prices to be positive. Compared to settlement-free peering, positive direct peering prices result in reduced premium tier prices. Directly connected video streaming providers increase their prices to compensate. However, the ISP only passes onto its customers a portion of the paid peering revenue.

However, this leaves unanswered the question of the impact on aggregate consumer surplus. It also leaves unanswered the question of what value of direct peering price maximizes aggregate consumer surplus. We attempt to answer those questions now.

We consider the direct peering price P^d to be an independent variable set by a regulator. The aggregate consumer surplus $CS(P^b_{CS_{reg}}, P^p_{CS_{reg}}, P^v)$ is a function of P^d. The regulator is presumed to set the direct peering price P^d so that it maximizes aggregate consumer surplus:

$$\begin{aligned} (P^b_{CS_{reg}}, P^p_{CS_{reg}}) &= \arg\max_{(P^b,P^b)} \pi^{ISP}(P^b, P^p, P^d_{CS_{reg}}, (r^{VSP}_{min}+1)C^v + P^d_{CS_{reg}}) \\ P^d_{CS_{reg}} &= \arg\max_{P^d} CS(P^b_{CS_{reg}}, P^p_{CS_{reg}}, P^d, (r^{VSP}_{min}+1)C^v + P^d). \end{aligned} \tag{17}$$

Equation (17) determines the resulting aggregate consumer surplus maximizing value of the direct peering price P^d, as well as the resulting broadband prices P^b and P^p and video streaming price P^v. However, the optimization problem is no longer analytically tractable. Thus, we will turn back to our numerical evaluation. Figure 4 shows the incremental consumer surplus as a function of the regulator chosen direct peering price P^d. The incremental consumer surplus is defined as the difference between the aggregate consumer surplus at the regulator chosen direct peering price P^d and at the direct peering price that maximizes ISP profit (P^d_{ISP}).

Aggregate consumer surplus is a uni-modal function of the direct peering price. We find that the direct peering price that maximizes consumer surplus is $P^d_{CS_{reg}} = \$2.34$. This is substantially less than the direct peering price that maximizes ISP profit (P^d_{ISP}=\$4.59). At direct peering prices lower than \$2.34, aggregate consumer surplus decreases principally because the premium tier price is too high, and this decreases the surplus of premium tier subscribers. At direct peering prices higher than \$2.34, aggregate consumer surplus decreases principally because the price of video streaming is too high, and this decreases the surplus of video streaming subscribers.

To understand why, we need to revisit the impact of the direct peering price on broadband tier prices and demand, and how these changes in price and demand affect aggregate

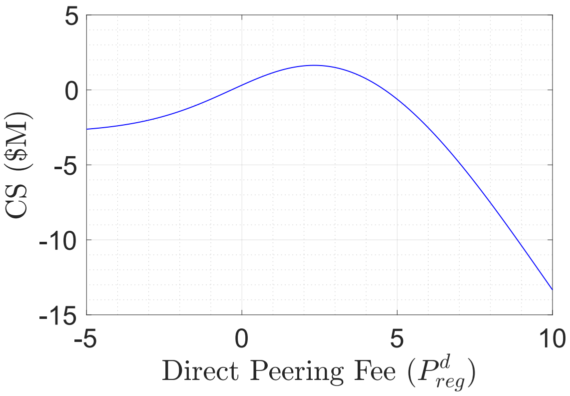


Figure 4: Effect of Direct Peering Fee on Incremental Consumer Surplus

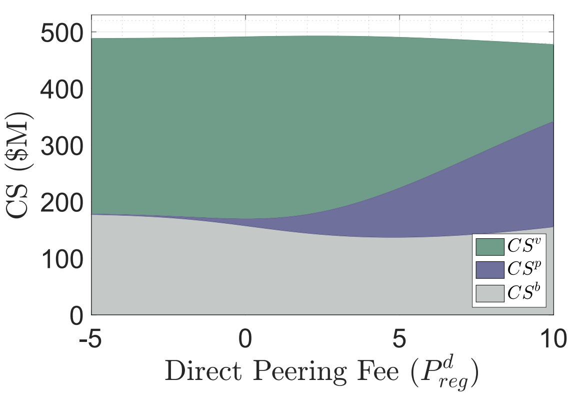


Figure 5: Effect of Direct Peering Fee on Consumer Surplus with Different Services

consumer surplus. We compare prices and demands in the case in which the ISP chooses the direct peering price to maximize profit ($P^d_{ISP} = \$4.59$) to the case in which the regulator chooses the direct peering price to maximize aggregate consumer surplus ($P^d_{CS_{reg}} = \$2.34$).

As we discussed in the previous section, a reduction in the direct peering price below that which maximizes ISP profit results in lower aggregate video streaming prices and increased premium tier prices. However, the amount of the increase in the premium tier price is less than the amount of the decrease in the aggregate video streaming price. Thus, the price of the premium tier with video streaming ($P^b + P^p + P^v$) decreases. These changes in prices cause some premium tier subscribers without video streaming to downgrade to the basic tier, and some to start subscribing to video streaming.

These changes in prices and demand affect aggregate consumer surplus. Figure 5 shows the aggregate consumer surplus of all subscribers to the basic tier, to the premium tier without video streaming, and to the premium tier with video streaming. A reduction in the direct peering price below that which maximizes ISP profit results in increased demand for the basic tier, but with basic tier prices virtually unchanged. The result is that the aggregate consumer surplus of basic tier subscribers increases. A reduction in the direct peering price also results in increased premium tier prices and decreased demand for the premium tier without video streaming. The result is that the aggregate consumer surplus of premium tier subscribers without video streaming decreases. Finally, a reduction in the direct peering price results in decreased prices of the premium tier with video streaming and increased demand. The result is that the aggregate consumer surplus of premium tier subscribers with video streaming increases. The aggregate consumer surplus is the sum of these three. As the direct peering price decreases from the price that maximizes ISP profit (P^d_{ISP}=\$4.59) to the price that maximizes consumer surplus ($P^d_{CS_{reg}} = \$2.34$), the increase in the aggregate consumer surplus of basic tier subscribers and premium tier subscribers with video streaming dominates the decrease in the aggregate consumer surplus of premium tier subscribers without video streaming. However, at direct peering prices below the price that maximizes consumer surplus ($P^d_{CS_{reg}} = \$2.34$), the opposite is true.

We can now evaluate the stakeholder claims about the effect of paid peering on consumer surplus. Recall that ISPs assert that paid peering fees increase aggregate consumer surplus whereas content providers assert that they decrease aggregate consumer surplus. The direct peering price that maximizes aggregate consumer surplus is below the price that maximizes ISP profit. Using our numerical parameters, we found that the direct peering price that maximizes aggregate consumer surplus is $P^d_{CS_{reg}} = \$2.34$, whereas if unregulated the ISP would choose $P^d_{ISP} = \$4.59$. Furthermore, we found that aggregate consumer surplus is \$1.65M higher at the direct peering price that maximizes aggregate consumer surplus than at the direct peering price that maximizes ISP profit. However, we also found that when the incremental ISP cost per video streaming subscriber is $C^d = \$3.00$, aggregate consumer surplus is \$1.33M higher at the direct peering price that maximizes aggregate consumer surplus than at settlement-free peering ($P^d = \$0$). Thus, neither settlement-free peering nor paid peering with an ISP-determined price maximizes consumer surplus.

7. The Effect of the Incremental ISP Cost C^d Per Video Streaming Subscriber

The direct peering price that maximizes aggregate consumer surplus depends critically on the incremental ISP cost C^d per video streaming subscriber. Without knowledge of this cost, we cannot say whether the direct peering price that maximizes aggregate consumer surplus is negative, zero, or positive. We consider this issue now.

Figure 6 shows the direct peering prices that maximize ISP profit and aggregate consumer surplus as a function of the incremental ISP cost C^d per video streaming subscriber.[7] The direct peering price that maximizes aggregate consumer surplus, $P^d_{CS_{reg}}$, increases nearly linearly, from -\$1.80 to \$2.34 as C^d increases from \$1.12 to \$3.00. Notably, it is positive when $C^d > \$0.68$, but negative at lower values of C^d. Recall that the incremental ISP cost C^d per video streaming subscriber depends on both the incremental Internet usage of video streaming subscribers over non-subscribers and the length of the path on the ISP's network. As video content providers interconnect with the ISP closer to consumers, the incremental ISP cost C^d per video streaming subscriber decreases, and may be negative if the interconnection point is close enough to the consumer. In contrast, if the interconnection point is far from the consumer, then the incremental Internet usage may dominate and C^d may be positive.

The direct peering price that maximizes ISP profit, P^d_{ISP}, increases nearly linearly with the incremental ISP cost C^d per video streaming subscriber, from \$0.00 to \$4.59 as C^d increases from \$1.12 to \$3.00. Notably, the incremental ISP profit $P^d_{ISP} - C^d$ per video streaming subscriber remains positive at all values above $C^d = -\$1.12$, and indeed increases with higher values of C^d.

The effect on consumers is qualitatively similar, but different in magnitude. When $C^d = \$3.00$, premium tier subscribers without video streaming would pay \$70.00 at the

[7] For each value of C^d, we determine the numerical parameters (μ_b, μ_p, μ_v, C^b, C^p, and P^d) using the method discussed in Section 4.2. Thus, not only does C^d direct affect the direct peering prices, it also indirectly affects all prices and demands.

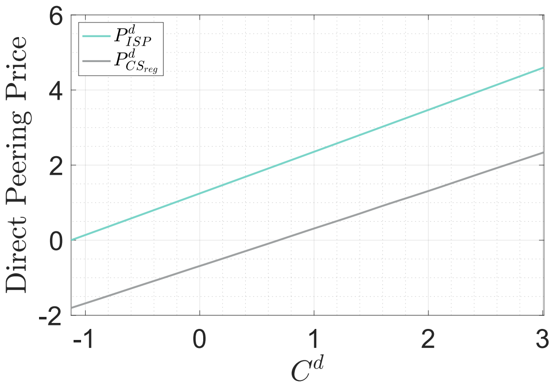


Figure 6: Effect of the Incremental ISP Cost Per Video Streaming Subscriber on the Direct Peering Price

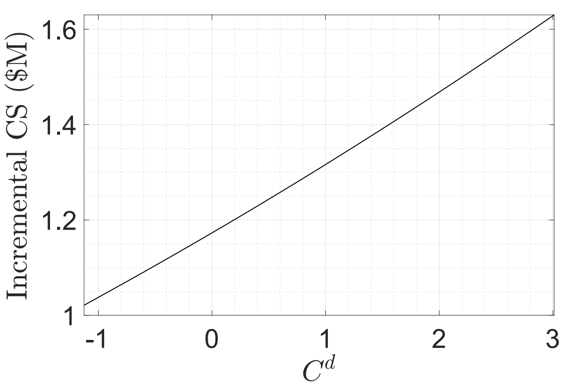


Figure 7: Effect of the Incremental ISP Cost Per Video Streaming Subscriber on the Incremental Consumer Surplus

ISP chosen direct peering price (P^d = \$4.59) but \$71.69 if the regulator sets the direct peering price to maximize consumer surplus (P^d = \$2.34), and premium tier subscribers with video streaming would pay \$96.19 at the ISP chosen direct peering price but \$95.61 at the regulator chosen direct peering price. Thus, regulation of the direct peering price results in premium tier subscribers without video streaming paying \$1.69 more and in premium tier subscribers with video streaming paying \$0.58 less; however the regulated direct peering price also increases demand for video streaming from 37.5% to 42.6%.

When $C^d = -\$1.12$, premium tier subscribers without video streaming would pay \$70.00 at the ISP chosen direct peering price but \$71.37 at the regulator chosen direct peering price, and premium tier subscribers with video streaming would pay \$91.59 at the ISP chosen direct peering price but \$91.15 at the regulator chosen direct peering price. Thus, regulation of the direct peering price results in premium tier subscribers without video streaming paying \$1.37 more and in premium tier subscribers with video streaming paying \$0.44 less; however the regulated direct peering price also increases demand for video streaming from 37.5% to 42.3%.

Finally, we revisit our evaluation of stakeholder claims about broadband prices, ISP profit, and consumer surplus, under different values of the incremental ISP cost C^d per video streaming subscriber. If C^d = \$3.00, we found that paid peering should be expected to reduce the price of the premium tier, but this reduction in broadband price is more than offset by an increase in video streaming prices. At lower values of C^d, paid peering still should be expected to reduce the price of the premium tier, but less so. Similarly, neither the change in ISP profit nor the change in video streaming profit is very sensitive to C^d.

If C^d = \$3.00, we found that aggregate consumer surplus is \$1.65M higher at the direct peering price that maximizes aggregate consumer surplus than at the direct peering price that maximizes ISP profit, but that aggregate consumer surplus is also \$1.33M higher at the direct peering price that maximizes aggregate consumer surplus than at settlement-free peering (P^d = \$0). Figure 7 shows the difference between the aggregate consumer surplus at ISP-chosen direct peering price and that at the direct peering price that maximizes consumer surplus, for various values of C^d. We observe that the incremental consumer surplus is significant at all values of C^d, rising from \$1.02M to \$1.63M as C^d increases from \$1.12 to \$3.00.

The incremental ISP cost C^d per video streaming subscriber, however, does have a large impact on the optimal direct peering price. The direct peering price that maximizes consumer surplus is strongly correlated with C^d. At values of $C^d > \$0.68$, settlement-free peering is too aggressive. and the regulator should limit the direct peering price to at least \$2.00 less than the ISP-chosen direct peering price. At negative values of C^d, settlement-free peering is too timid, and the ISP should pay content providers for direct peering at locations so close to the consumers. At small positive values of C^d ($0 < C^d < \$0.68$), the ISP bears a cost, but the direct peering price that maximizes consumer surplus is negative.

8. Conclusion

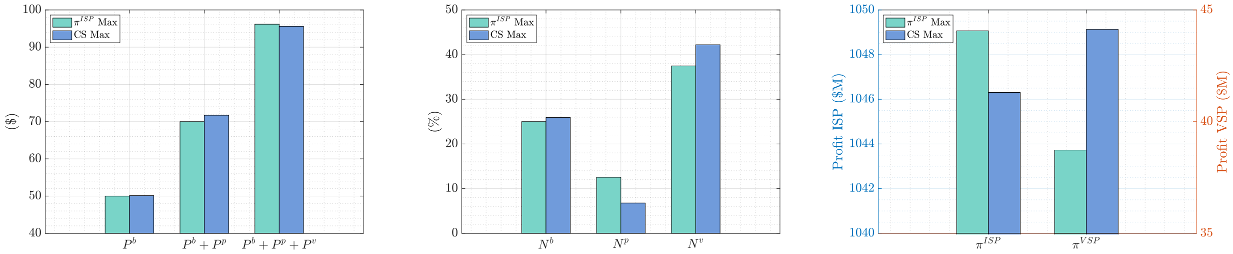
ISPs and content providers disagree about the effect of paid peering on broadband prices. ISPs assert that the revenue they generate from paid peering fees is used to lower broadband prices, whereas content providers assert that paid peering fees increase ISP profit but do not affect broadband prices.

To address this debate, we modeled a monopoly ISP offering two tiers of service. Consumers decide whether to subscribe to broadband and if so to which tier, and whether to subscribe to video streaming services. We modeled demand for the broadband tiers and video streaming services based on these consumer choices, and evaluate the resulting ISP profit, video streaming profit, and consumer surplus.

To focus on the effect of direct peering fees, we considered a two-sided model in which a profit-maximizing ISP determines broadband prices and the direct peering price and in which video streaming providers choose their price based on the direct peering price. Numerical parameters were chosen based on public information about broadband and video streaming prices and subscription.

We also determined the direct peering fees that maximize consumer surplus such as a regulator may set. We compared the effect of an ISP-chosen direct peering fee with a regulator-chosen direct peering fee. Figure 8 summarizes our results. We find when that a regulator sets the direct peering price to maximize consumer surplus, its chooses a lower direct peering price than does the ISP. As a result, video streaming prices drop to reflect the lower video streaming costs. However, the ISP then increases the price of the premium tier, recouping most of its loss from the lower direct peering price and regaining some of the increased consumer surplus from lower video streaming prices.

These changes in prices affect the demand for broadband and for video streaming. When the regulator steps in, the reduction in the price of video streaming, combined with the increase in the price of the premium tier, creates two shifts. First, some premium tier subscribers with moderate utility from video streaming will start subscribing, due to the reduced sum of the premium tier price and the video streaming price. Second, some premium



(a) Prices (b) Demand (c) Profit

Figure 8: Comparison between different policies

tier subscribers with low utility from video streaming will downgrade to the basic tier, due to the increased premium tier price.

Our results show that the claims of the ISPs and of the content providers are both incorrect. When an ISP chooses direct peering prices, some of the revenue from these fees is used to decrease the price of the premium tier, but some of the revenue increases ISP profit. In contrast, when a regulator sets direct peering prices to maximize consumer surplus, the lower price stimulates significant additional demand for video streaming.

ISPs and content providers also disagree about the effect of paid peering on consumer surplus, and ultimately about whether direct peering prices should be regulated. ISPs assert that paid peering increases consumer surplus because it eliminates an inherent subsidy of consumers with high video streaming use by consumers without, whereas content providers assert that paid peering decreases consumer surplus because paid peering fees are passed onto consumers through higher video streaming prices and because there is no corresponding reduction in broadband prices. As a result, ISPs argue that the market should determine direct peering prices, while content providers argue that they should be entitled to settlement-free peering if they interconnect with the ISP close enough to consumers.

Our results show that the direct peering price that maximizes consumer surplus is lower than the direct peering price an ISP would choose. Although an ISP-chosen direct peering price does eliminate an inherent subsidy of video streaming (if there is a positive incremental ISP cost per video streaming subscriber), the ISP-chosen direct peering price substantially exceeds this incremental cost. As a result, the ISP-chosen direct peering price reduces consumer surplus, largely because it reduces demand for video streaming.

However, it does not follow that settlement-free peering is always the policy that maximizes consumer surplus. When there is a moderate incremental ISP cost per video streaming subscriber, the direct peering price that maximizes consumer surplus is positive, but lower than the ISP-chosen price. This positive price is beneficial for consumers because the incremental ISP cost for video streaming is paid by video streaming subscribers. In contrast, if content providers bring the content closer to consumers, there may be a negative incremental ISP cost per video streaming subscriber, in which case the direct peering price that maximizes consumer surplus is negative. In this situation, the content provider should be entitled to settlement-free peering, or even to be paid by the ISP.

These results are not the end of the story. In this paper, we only considered direct interconnection between content providers and an ISP. However, despite the reduction in the percentage of Internet traffic passing through a transit provider, it would be useful to examine the decision of a content provider choosing between direct interconnection with an ISP and transit service from a transit provider. Large ISPs assert that direct interconnection is a competitive alternative to indirect connection through transit, whereas content providers assert that ISPs retain a terminating monopoly on both. Further research is also warranted to examine the incremental ISP cost for video streaming. An ISP's costs for transporting Internet traffic depends on whether the traffic is carried across the ISP's core and middle mile networks, as well as the ISP's access network. Research could consider how routing and interconnection affect ISP costs, and in particular, the incremental ISP cost per video streaming subscriber. Finally, policymakers could benefit from further research on the impact of direct peering fees on the video marketplace. Although we found that ISP-determined direct peering prices likely exceed related costs and do not maximize consumer surplus, we found that they likely affect video streaming demand more than they affect either consumer surplus or ISP profits. A model that evaluates the impact on competition between an ISP's video streaming products and competing video streaming products may be insightful.

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