Steering Incentives on Platforms: Evidence from the Telecommunications Industry*

Brian McManus Aviv Nevo Zachary Nolan
Jonathan W. Williams

September 6, 2019

Abstract

Internet Service Providers (ISPs) offer both TV packages and access to the internet, which allows customers to view streaming video that competes with TV and can increase ISPs' network costs. This provides ISPs with an incentive to steer its customers toward more profitable subscriptions and viewing choices. We study these incentives using a unique dataset that documents individual consumers' internet usage choices and TV subscriptions, all in a setting where an ISP introduced a new policy of internet usage allowances and overage charges. We extend the textbook monopoly bundling model to describe the policy's main effects, including how ISPs' incentives to encourage or discourage streaming video varies with its ability to steer consumers. We then analyze empirically the price policy's impact on consumers' choices. Consistent with our theoretical model, the new policy steered internet-only consumers into bundled TV and internet subscriptions; this effect was greatest for heavy users of streaming services most similar to conventional TV. Internet usage growth was curtailed for consumers of all types, regardless of choices about subscriptions, and it reduced usage of and subscriptions to third-party streaming video services. Finally, we discuss the implications of these findings for antitrust and regulatory issues in the telecommunications industry, including Net Neutrality.

Keywords: Steering, Bundling, Telecommunications Industry, Broadband Internet, Net Neutrality

JEL Codes: L11, L13, L96.

*We are grateful for the the North American ISP that provided the data used in this paper. We thank Shane Greenstein and Jeff Prince for comments, as well as audiences at Indiana-Kelly, Penn State, Yale, FCC, and the NBER's IT and Digitization workshop. Zach Nolan and Jonathan Williams thank Cable Television Laboratories, Inc., and its member organizations, for their support of this work. McManus: Department of Economics, University of North Carolina at Chapel Hill, mcmanusb@unc.edu; Nevo: Department of Economics and Wharton School, University of Pennsylvania, nevo@upenn.edu; Nolan: Department of Economics, Duke University, zach.nolan@duke.edu; Williams: Department of Economics, University of North Carolina at Chapel Hill, jonwms@unc.edu.

1 Introduction

In a variety of industries, consumers access products or services through a platform, or gatekeeper. In some cases, the gatekeeper has incentives to steer consumers towards specific choices in order to either reduce costs or to increase demand for the gatekeeper's own products. For example, in health care markets consumers enroll in an insurance plan and then access health care providers mostly through the insurer's network. This creates incentives for the insurance company (the gatekeeper) to steer consumers towards certain providers, and generally to try to guard against moral hazard in the consumption of health services. Similarly, consumers might reach online shopping sites through a search platform that could have incentives to steer consumers either to its own sites or sites that pay a higher fee. In these settings, the gatekeeper faces a tradeoff: access to many products and services creates value to the platform, but for the above reasons there may be benefits from restricting shoppers' choices. This tension leads to concerns that the platform may try to gain at the expense of certain third-party firms. The platform might do so by designing contracts and pricing schedules that incentivize consumers to switch away from these third party firms or by trying to reduce the quality of the firms' products or services.[1]

In this paper, we analyze a situation where an Internet Service Provider (ISP), which serves as the gatekeeper to internet usage, has incentives to steer consumers towards its bundles that include TV service while also reducing consumers' internet usage. We show that the ISP can achieve this goal (1) by introducing a nonlinear price that affects consumers' decisions, or (2) by reducing the quality or availability of over-the-top (i.e., streamed) video. The latter may be considered a violation of the principle of Net Neutrality, the position that an ISP should treat all content equally. Interestingly, we show that the two tools interact: the incentive to reduce content quality may be diminished if it is possible for the ISP to steer consumers' choices. Armed with this theoretical insight, we turn to the data and use a change in an ISP's pricing policy to estimate several elasticities of consumer demand.

We proceed in several steps. First, we document facts that show that the ISP has an incentive to steer consumers towards bundles that include TV services. The facts include: the increase in the popularity of online video services that potentially compete with traditional TV provided by the ISP, and an increase in the share of consumers who elect to drop their traditional TV service. Second, we write down a

[1]For example, in June 2017 the European Commission fined Google "€2.42 billion for abusing dominance as search engine by giving illegal advantage to own comparison shopping service." In March 2018, Spotify filed a complaint with the European Commission saying that Apple, the gatekeeper of the App Store, "has introduced rules to the App Store that purposely limit choice and stifle innovation at the expense of the user experienceessentially acting as both a player and referee to deliberately disadvantage other app developers."

simple model that allows us to understand the incentives of consumers and the ISP in this setting. Since the ISP offers TV, internet, and a TV-internet bundle, we start with a traditional bundling model and modify it to fit the specifics of the industry. Next we turn to the data and show the effect of the strategies employed by the ISP. Specifically, we show that the ISP is able to steer consumers from internet-only subscriptions back into the bundle, and additionally it induces consumers to upgrade their internet tiers. Steering's impact spills over from the ISP to third-party streaming video firms, which lose subscribers and streaming volume.

To document the relevant industry facts, we analyze unique household-level panel data from a North American ISP. The data include information on internet usage and TV subscription choices of a large number of households over nearly one year. In addition, during our sample period, the ISP implemented usage-based pricing (UBP) in a subset of markets. The UBP takes the form of a menu of three-part tariffs, each of which includes an access fee, an internet usage allowance, and an overage charge. The policy's introduction offers a rare opportunity to measure consumers' responses to steering strategies in this industry. The data include detailed information on each household's internet data usage at an hourly frequency, and whether they also have a TV subscription. Central to our analysis, and in contrast to previous academic work on the telecommunications industry, we observe which over-the-top video (OTTV) services a household uses and the volume of traffic generated by these services.

First, we show that in our sample OTTV services (e.g., Netflix, Hulu) account for nearly two thirds of all data usage on the internet. The popularity of OTTV creates tradeoffs for the ISP. On one hand, the popularity of OTTV increases the value of the internet service sold by the ISP. On the other hand, the ISP also sells traditional TV services that potentially compete with OTTV services. Further, OTTV services generate substantial network costs, in contrast to traditional TV services for which costs are essentially fixed.[2] Second, we show that households with subscriptions to the ISP's TV service use much less data and engage less frequently with OTTV. These differences are not merely due to selection into different types of subscriptions; we document that when a household cuts the cord (i.e., drops TV), it increases its internet usage by nearly one quarter. Overall, cord-cutting has accelerated in the U.S. during recent years.

Together, these facts imply that improvements in OTTV quality and access create the risk of higher cost and lower revenue to the ISP, and therefore create an incentive to steer customers towards TV services or even foreclose some OTTV services. The incentives to foreclose some services has been discussed in the context of Net Neutrality,

[2]The differences in the two services' costs are related to OTTV's "unicast" nature, which can have a unique transmission for each consumer, in contrast to the "broadcast" nature of traditional TV.

where the discussion has focused on upstream pricing, between the platform and the content providers. We show that some of the same effects can be achieved downstream by the ISP steering consumers. We should note that, while steering may impose some costs on consumers, it can be socially beneficial if the steering strategies help align consumers' choices with the asymmetry in the firm's costs for OTTV versus traditional TV.

Motivated by these facts, and in order to understand how steering might work in this industry, we write a simple model of bundling that includes TV and internet subscriptions in the presence of competitively supplied third-party OTTV services. We show that many of the phenomena described above can be captured by adding two elements to the standard bundling framework: quantity choices by consumers for the services they receive, and a parameter that describes internet subscribers' access to OTTV services. The model can match the pattern we see in the data: an increase in streaming video access, all else fixed, leads to increased cord-cutting behavior in which consumers drop their TV subscriptions and increase OTTV use. As we discussed above, this reduces the ISP's revenue and increases its costs. While the ISP can steer consumers somewhat by adjusting subscription prices and the bundle discount alone, it can have a greater impact on consumers' choices once we expand the model and allow the ISP to set usage allowances and offer internet service tiers that vary by speed and allowance. An internet usage allowance encourages some consumers to keep their video subscriptions while limiting internet use. When the ISP adds internet tiers which associate greater allowances with higher prices, the firm can extract more revenue from high demand consumers. While some high demand consumers experience a reduction in surplus when their internet use is capped or more expensive, some low demand consumers may gain access to the market because subscription prices can fall when set jointly with an allowance. Contrary to concerns that usage-related prices or constraints are at odds with Net Neutrality's goal of robust third-party content creation, we show that ISPs may have an incentive to improve OTTV quality when these pricing tools are available.

We next turn to empirical analysis, where we use temporal and cross-sectional variation in UBP to investigate how consumers responded to the ISP's introduction of these three-part tariffs for internet service. We find that the new usage-based prices were able to steer a significant share of internet-only households into the bundle, where they can receive video entertainment through traditional TV. New bundle subscriptions were most likely for households who used OTTV services with content that is very similar to traditional TV. The new prices also had an impact on cord-cutting behavior. While overall cord-cutting rates were not substantially affected by UBP, a much greater share of cord-cutting was concentrated among households that also upgraded their internet usage tiers. An upgrade reduces the chance of a household receiving an overage charge, but it also implies a smaller reduction in revenue for the ISP relative to cord-cutting alone. The increase in usage tier upgrades occurred throughout the ISP's subscriber population. The consumers most likely to upgrade were the heaviest users, who were the most likely to receive overage charges when UBP was implemented.

In addition to the extensive margin subscription choices, we examine an additional impact of the ISP's steering strategy: the amount of growth in a household's total internet usage. Internet usage (in gigabyte volume) has grown by about 40% per year during the past decade, and this has spurred widespread investment in network capacity. Households that upgraded their tiers increased their usage during the sample period, roughly keeping pace with consumers not exposed to UBP. On the other hand, usage growth was substantially lower among households exposed to UBP that did not upgrade.

These steering outcomes – increased bundle subscriptions and upgraded internet tiers – represent an effective reallocation of OTTV surplus from households to the ISP. The consumers' responses also validate some of the assumptions underlying our theoretical model, which provides support for its conclusions on the varying incentives of ISPs to stimulate OTTV. Despite the fact that some UBP outcomes can have negative impacts on some consumers, ISPs' incentives to create new content and expand their networks may be stronger when ISPs capture a greater share of total surplus from OTTV.

In addition to these direct impacts on the ISP and its subscribers, the steering strategy has significant effects on OTTV firms. Netflix subscriptions fell significantly when UBP was introduced, with subscribers to the ISP's bundle having a greater response than internet-only subscribers. The same qualitative outcomes also occur for Netflix usage quantity, but in greater magnitudes than the subscription responses. While Netflix offers a mix of original programming and older TV shows and movies, other OTTV services like Hulu and SlingTV offer content that is much more similar to conventional TV. These services are more strongly affected by UBP than Netflix is, which highlights how steering's impact in this setting is closely related to the substitutability of conventional TV and internet content. The ISP's ability to direct consumers across video entertainment sources may play a prominent role in future antitrust or regulatory debates, such as evaluating vertical mergers between content and distributor firms, or more horizontal mergers involving firms that compete in either content production, video distribution, or both.

Related literature Our results contribute to a growing literature on the rapidly changing telecommunications industry. Streaming video is an increasing share of all video entertainment, and many households subscribe to one or more streaming services such as Netflix, Amazon Prime, or Hulu. Due to data availability and earlier sample periods, where internet usage was less important, much of the previous research on video programming has focused on traditional TV (Crawford et al. (2017), Crawford and Yurukoglu (2012), Crawford and Shum (2007), and Crawford and Shum (2015)).

Our data also provide an opportunity for novel contributions on the value consumers receive from access to the internet. We follow Nevo et al. (2016), Malone et al. (2016), and Malone et al. (2014), who use high-frequency data to study subscriber behavior on residential broadband networks. These studies were not able to separate streaming video activity from other internet usage, however, and therefore were unable to consider ISPs' steering incentives due to OTTV's role in the interaction between internet and television services. Other studies of the demand for and consumers' value from broadband services include Goetz (2016), Tudon (2018), Goolsbee and Klenow (2006), Dutz et al. (2009), Rosston et al. (2013), Greenstein and McDevitt (2011), Goolsbee and Klenow (2006), Edell and Varaiya (2002), Varian (2002), and Hitte and Tambe (2007).

Relationships between ISPs and internet content providers is an active area for public policy, especially concerning merger approval and net neutrality.[3] These policy issues converge with the issue of vertical mergers between ISPs and media companies, which can affect ISPs' profits from various content sources and therefore induce steering activity. The literature on these issues largely began with Wu (2003), who introduced the term "net neutrality" and provides an excellent summary of the issues. Lee and Wu (2009) and Greenstein et al. (2016) discuss and review the literature on the topic. However, most of the existing economic analysis of the topic is theoretical: Economides and Hermalin (2012), Armstrong (2006), Bourreau et al. (2015), Choi et al. (2015), Choi and Kim (2010), Economides and Tag (2012), Gans (2015), Economides and Tag (2016), Reggiani and Valletti (2016), and Sidak (2006). Our empirical analysis on steering incentives complements these theoretical studies by providing insight into relevant elasticities for the debate.

More generally, our model and empirical analysis also contribute to literatures on firms' strategic efforts to steer and sort heterogeneous consumers across product menus. Ho and Lee (2017), Liebman (2017), and Raval and Rosenbaum (2017) study how insurers influence patients' choices across medical providers. Barwick et al. (2017) examine conflicts of interest and steering by residential real-estate brokers. Crawford et al. (2017) consider similar incentives in cable TV markets, and estimate the value

[3]The FCC's 2015 Open internet Order prevented ISPs from discriminating among various online applications. This order limited ISPs' ability to reduce usage of video services from some third-party providers. The FCC voted in 2017 to roll back the order, and future policy in this area continues to be debated.

to cable distributors of including vertically integrated versus non-integrated sports networks in their channel bundles.

The incentive to degrade product quality for discriminatory or steering purposes, as is present in our model, is related to the classic work of Mussa and Rosen (1978), which Crawford and Shum (2007) apply in the context of the telecommunications industry. In the bundling literature, Armstrong (2013) and Gentzkow (2007) study how the consumption of one product in a bundle affects utility from other products, which is similar to the relationship between OTTV and TV that we study. Chu et al. (2011) and Crawford and Yurukoglu (2012) empirically explore how variations on bundling and other pricing strategies can affect firms' profit and consumer welfare. Nonlinear-pricing strategies similar to those we examine have been studied in broadband markets (Economides and Hermalin (2015), Lambrecht et al. (2007)), phone service contracts (Miravete (2003), Grubb (2015), and Grubb and Osborne (2015)), and other markets (Hagemann (2017), McManus (2007)).

2 Data and Industry Background Facts

In this section we introduce the data we use for our analysis and provide some basic descriptive statistics. We also present two industry patterns that motivate the analysis that follows in the next two sections. First, we study OTTV usage in our data. Internet usage has been growing steadily over the last few years. This increase is largely driven by an increase in streaming video. Indeed, streaming video's dominant role is part of an important trend that has unfolded over the past decade to reshape the telecommunications industry.[4] In our sample, 60% of internet usage is for OTTV. Furthermore, third-party OTTV adoption and usage is higher among internet-only subscribers.

Second, the emergence and popularity of OTTV services coincides with a trend in "cord cutting." Between 2015 and 2017, the number of US households that received video exclusively through a broadband connection almost doubled to about 5.4M. We show that households that drop their video service increase their internet usage (and similarly household that add a video service decrease their internet usage). These patterns suggest substitution between OTTV and TV services. This also has important implications for ISPs. When a household cuts the cord, the ISP loses the margins associated with the video service and experiences higher cost of transmitting internet service. We demonstrate the revenue implications below and use them to motivate the analysis in the next section, in which we provide a model that allows us to study ISPs'

[4]Between 2012 and 2017, per-person average daily use of online video increased twenty-fold from 3.5 minutes to 72 minutes. This usage increase coincides with the emergence and rapid growth of several prominent firms that offer OTTV services. In 2015 about 40% of US households subscribed to a streaming service such as Netflix (40M subscribers), Amazon Prime (14.5M), or Hulu (7M).

incentives.

2.1 Data

The data we use come from a North American ISP.[5] Our sample is drawn from a handful of markets during a one-year period in the mid-2010s, and it is nationally representative in terms of demographics, service offerings, and usage patterns. During our one-year sample period we observe roughly 350,000 consumers' billing information, subscriptions, and internet usage.[6]

Like most North American ISPs, this ISP offers internet and TV services via mixed bundling, giving discounts off of stand-alone prices when consumers subscribe to both services.[7] 30% of the ISP customers have internet-only subscriptions, and the remaining 70% subscribe to an internet-TV bundle; no ISP customers in the data we see subscribe to TV alone. The ISP also offers tiers of internet service that are differentiated by speed and, as we discuss below, usage allowance in some cases.

An important feature of our data, which will help us in the analysis that follows, is the introduction of UBP in some markets partway through the sample period. The UBP is implemented through a menu of several service tiers that consumers can choose from, where each tier is a three part tariff. Depending on the service tier the household chooses, they are allocated a monthly usage allowance in gigabytes (GBs). Usage up to this allowance does not entail any additional charge, but if the allowance is exceeded the household is charged a lump-sum fee and receives a small top-up allowance. If a household exhausts this top-up allowance, it is charged again and the household receives another top-up. During the treatment period, 8% of sample households (across all markets) use more than the allowance associated with their tier.

The ISP faced similar competitors across the markets we observe, with no apparent variation that is correlated with UBP's introduction. Satellite TV was available in each market, as was internet via DSL lines. During our sample period in the markets we study, the ISP offered internet service on a substantially higher-speed and higher-capacity network than the alternatives.[8]

For each household in the sample, we observe download and upload volume for

[5] Our agreement with the ISP prevents us from identifying the firm or any details that could be used to infer its identity. This includes the specific markets served, details about the implementation of UBP, and some characteristics of the ISP's product offerings.

[6] 72% of consumers in the sample are active subscribers for the full sample period. 16% of consumers terminate their subscriptions and 14% start subscriptions after the sample begins.

[7] The ISP also offers telephone service, which about 40% of its customers subscribe to. We do not use the telephone service information in this paper.

[8] Despite the rapid usage growth within our sample, we see little evidence that congestion affected internet use. Packet loss, which is a quality disruption often caused by congestion, averaged less than 0.01% during peak hours in our sample. See Malone et al. (2016) for a study of the impact of congestion on broadband networks.

each hour, although for much of the analysis we aggregate usage to the daily level. Households in the sample use a mean (median) of 4.7GB (1.4GB) of internet data per day. Internet usage differs substantially across households. Average usage in the highest-priced (and highest-speed) tier is nearly seven times as in the lowest-priced tier. Within-tier usage dispersion is also substantial; coefficients of variation range from 1.67 to 2.05 across tiers. Across combinations of TV and internet service, internet-only subscribers have mean (median) internet usage that is 61% (137%) greater than bundle subscribers. Overall, internet usage increased at a 44% annualized rate during our sample period. The growth rates were largest, on average, among consumers who began the sample at lower usage levels, but the increase in total usage volume is driven more by initially high-usage households.

Within a household's total usage, we observe the application (e.g., Netflix) or protocol (e.g., File Transfer Protocol or FTP) generating each byte used by a consumer, but not the specific content (e.g., particular movie title or website). In Appendix Tables 5 and 6 we present a simple grouping of the applications.

2.2 OTTV Usage

In order to further explore internet usage in our data, we divide usage into five major categories: Browsing, Gaming, Music, Video, and Other. Video accounts for about 60% of all usage and browsing accounts for another 30%. The remaining share is divided approximately equally across the other categories. In Table 1, we provide a breakdown of OTTV streaming across specific applications, separately for households who purchase an internet-TV bundle and those that purchase internet only. Both adoption, defined as whether the household used the application at all during the sample period, and use intensity of OTTV applications are greater for internet-only households.

YouTube's free content is the most widely-accessed video application by households in our sample. Netflix, which offers a variety of original programming along with a library of previously distributed movies and television programs, is the most popular subscription service. HBO Go has a similar content structure to Netflix, while Hulu emphasizes opportunities to stream-on-demand TV shows that are currently airing on network TV. Other streaming services like SlingTV offer live TV over the internet.

2.3 Cord-Cutting

As we discussed above, the emergence and popularity of OTTV services, discussed in the previous sub-section, coincides with a trend in cord cutting. In this section we provide a detailed description of cord-cutters' changes in internet use in order to understand the ISP's motivation to steer consumer choices.

Table 1: OTTV Service Adoption and Daily Usage

Application	Adoption (%)	Avg. Use, All Households	Avg. Use, Adopters
internet-only subs			
HBO Go	11.3	0.03	0.25
Hulu	22.6	0.14	0.39
Netflix	72.4	2.00	2.66
SlingTV	2.93	0.05	1.59
YouTube	92.5	0.95	1.02
Bundle subs			
HBO Go	10.1	0.02	0.20
Hulu	12.0	0.05	0.19
Netflix	62.6	1.17	1.81
SlingTV	0.53	0.01	1.15
YouTube	84.5	0.65	0.76

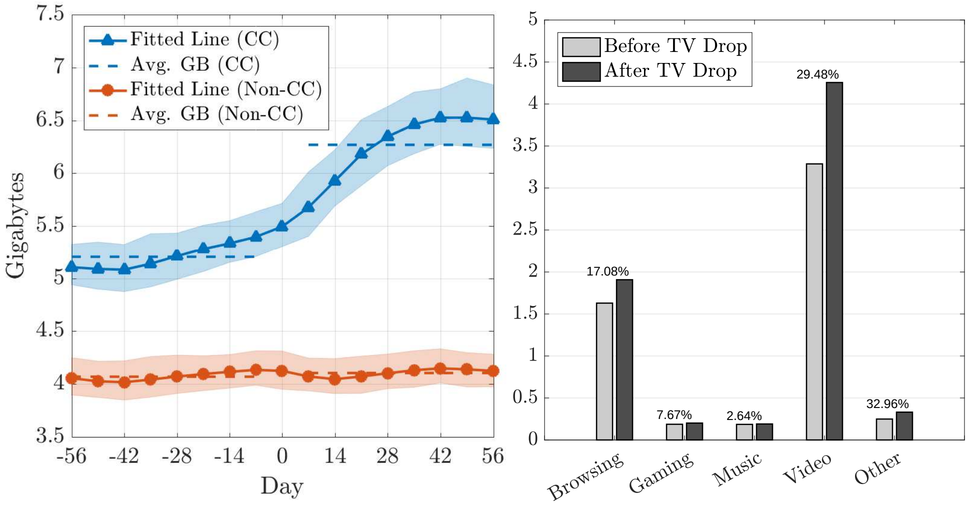
Notes: This column labeled "Adoption" reports the share of households that we see using each OTTV service. Use is the average daily consumption of these services in GBs. "internet-only subs" refers to households who subscribe to internet-only plans in that month, while "Bundle subs" are households that subscribe to a internet-TV bundle in that month.

In Figure 1 Panel (a) we plot the shift in average internet usage by cord-cutting households, and, for comparison, we also plot the average usage of consumers who hold on to their TV subscriptions. The line labeled as "Fitted Line (CC)" is the average per-household usage on each day of the 12-week window centered around the date of subscription change. The line labeled "Fitted Line (Non-CC)" is the daily average per household, for households who did not drop their TV service. We compute the average for each calendar date and then average across the dates to match the windows presented for the cord cutters. We supplement the fitted lines with average levels of internet usage in the weeks before and after cord-cutting. Together, these numbers show that the average (eventual) cord-cutter's internet usage begins approximately 25% higher than other subscribers, and increases by 23% after cutting the cord (4.9 GB/day to 6.0 GB/day).[9] Thus, the individuals who drop TV in our sample tend to be heavier internet users. Unfortunately, we do not have any additional household demographics to further explore drivers of selection.

We explore the nature of cord-cutters' changing internet usage by decomposing the 23% increase in traffic across types of applications. In Figure 1 Panel (b) we provide the change in usage across Browsing, Gaming, Music, Video Streaming, and Other

[9] Our 23% estimate of cord-cutting's impact is likely to be conservative. The data suggest that many consumers "prepare" to drop their TV subscriptions by adding and experimenting with online video services during the weeks before cutting the cord. Cord-cutters' increased usage begins prior to the subscription change date, and consumers who do not alter their subscriptions do not have a corresponding usage change.

Figure 1: *Average Daily Usage and OTTV Adoption for Cord-Cutters*



(a) Usage (b) OTTV Adoption

Notes: Panel (a) summarizes the average daily usage (GBs) of internet subscribers in the eight weeks before and after dropping TV services (upper plots) in comparison to all other internet subscribers (lower plots). The points are average daily usage, and the dotted lines are average usage across days before and after the change. One week on either side of the cord-cut date is omitted. Panel (b) summarizes the average daily usage (GBs) of online video applications by cord-cutters in the eight weeks before and after dropping TV services. For each application, the percent change in usage level between the two periods is shown above the two bars.

applications. The online activities that increase the most (online video and webpage browsing) are those that provide a fairly similar experience to watching TV. (Some online video that is delivered through websites, e.g. video on Facebook, appears in our data as browsing rather than video streaming.) Other entertainment applications (Gaming and Music) have increases in usage after cord-cutting, as do cloud-based backup services (e.g. Dropbox).

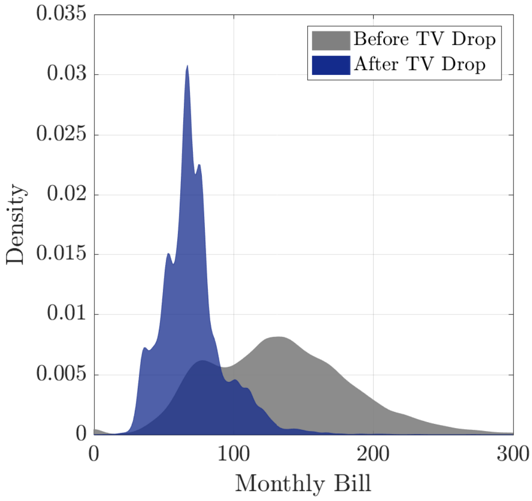
Some of the changes in Figure 1 Panel (b) are due to increased subscription to third-party OTTV services and increased usage. Netflix, Hulu, and SlingTV subscriptions increase by 21%, 69%, and 425% among households who cut the cord.[10] Within cord-cutting households, total Netflix usage increases by more than 30%. Households that add Hulu use it for 6% of their pre-cut internet usage; those who add SlingTV use it for 18% of their total pre-cut usage.[11]

Consumers who cut the cord sacrifice a portion of their available video entertain-

[10] Absolute increases in subscribers are of the same order of magnitude across services. The differences in percentage increases follow from differences in subscription levels among bundle households.

[11] Use of other relatively less-popular streaming services, like Amazon and HBO Go, actually decrease over this period, due in part to the end of seasonal programming. In addition, at the very end of our sample period we encountered encryption issues that interfered with our ability to observe these particular services.

Figure 2: *Estimated Total Subscriber Monthly Payments with OTTV*



Notes: This figure shows the distribution of estimated monthly payments by cord-cutters in the month before and after dropping pay TV. The total monthly operator bill is observed in the ISP billing data. Monthly OTTV expenditures are estimated using 2015 subscription fees for each of the video services observed in the usage data.

ment, and in exchange they pay substantially less for for the video services they receive. We analyze this change in payments by focusing on consumers who begin the sample with a bundle subscription and, at some point, drop TV but remain internet customers. Average payments from these consumers to the ISP fall by about 50%, from \$132 to \$68. We also calculate estimated total out-of-pocket spending by consumers to the ISP plus all subscription services using 2015 prices. In Figure 2 we plot the densities of consumers' total payments before and after cutting the cord. Average total spending per customer drops by half when the consumer drops a TV subscription. The variation around each distribution's mode is due to differences in consumers' subscription details (i.e., channel packages and internet tiers) and third-party OTTV subscriptions. The revenue reduction is accompanied by an increase in average internet usage, which requires greater data transmission and therefore greater network costs.

The usage, revenue, and cost impacts of cord-cutting may be reversed, of course, if the ISP can induce an internet-only subscriber to switch to the bundle. In Appendix Figure 9 we show that households who add TV subscriptions (i.e., "attach the cord") reduce their internet usage by about 25% within two weeks. This reduction is approximately equal in magnitude but opposite in sign to cord-cutting's impact on usage. We document in Appendix Table 7 that OTTV usage falls by more (proportionally and in absolute terms) than do Browsing, Gaming, and Music streaming.

3 A Simple Model

In this section we augment the textbook bundling model to present the main tradeoffs and incentives facing a gateway platform. We use a bundling model, since the bundling of internet and TV services is a key feature of the telecommunications industry. Internet service is a gateway to online applications, including OTTV. Therefore, the ISP faces a classic tradeoff of a gateway platform: improvements in OTTV increase the value of the ISP's internet product, but they also increase the ISP's costs while reducing demand for the ISP's TV service, both as a standalone product and in bundles. This tradeoff is further magnified because consumers, in addition to making discrete choices over subscription services, choose how much to use each product. This is important because the costs associated with building and maintaining internet networks are increasing in total traffic. We therefore incorporate a decision on usage into the textbook bundling model, and use the model to study the ISP's incentives to steer consumers away from OTTV using a variety of non-linear pricing options. We also investigate the incentives to directly impact the quality of OTTV video is available to consumers, and how this depends on the flexibility of nonlinear prices.

3.1 The Setup

Consider a market in which an ISP offers consumers access to two services: non-video internet (1) and video entertainment (2). An individual consumer's taste for "units" (e.g. hours) of services 1 and 2, relative to the outside option, is given by $v = (v_1, v_2)$. We normalize the consumer population to one and assume that consumers' tastes are distributed independently and uniformly on $[0, 1] \times [0, 1]$.

To access the services, the ISP offers consumers subscription plans. We begin by assuming that the ISP offers three plans: broadband internet access (i), TV (t), and a bundle (b) that includes both i and t. The firm's mixed bundling pricing strategy includes prices for the stand-alone plans (p_i and p_t) and a price for the bundle (p_b). A consumer can subscribe to one of the firm's three plans, $\{i, t, b\}$ or an outside option denoted by 0 that provides utility normalized to zero. To capture the presence of OTTV, we assume that consumers can access some video content (service 2) through an internet-only plan (i).

Utility

An individual consumer receives utility from consuming q_1 units of service 1 and q_2 units of service 2. These choices are affected by the consumer's tastes (v) and subscription plan. The quantity choice for video services, q_2, can include both traditional TV, q_2^t, and OTTV, q_2^i, with $q_2 = q_2^i + q_2^t$. For simplicity, we assume that a consumer has marginal utility equal to one for a service's units up to a satiation level equal to the taste parameter v, and then marginal utility is zero for any greater quantity.[12] For example, a consumer with taste v_2 and a TV-only subscription consumes $q_2 = q_2^t = v_2$ units of video entertainment through his TV and receives surplus of v_2 from this activity.

We incorporate OTTV into the model by assuming that a subscription to internet service allows a consumer to receive a fraction $\delta \in [0, 1)$ of his preferred video quantity. We initially treat δ as a given, but then explore the ISP incentives to impact it. The restriction $\delta < 1$ has several possible interpretations, including limited available OTTV content and diminished video quality, which could be due to transmission (e.g. congestion and buffering) or hardware limitations. We assume that OTTV is available at no additional expense to the consumer. The consumers marginal utility from video hours remains equal to one up to δv_2, where it falls to zero. This can be viewed as a scenario where a consumer enjoys v_2 distinct shows that are available on TV, but only the fraction δ of the shows are available through OTTV. To simplify the consumption choices of bundle subscribers, we assume that TV subscribers receive all video entertainment through TV, with $q_2^t = v_2$ and $q_2^i = 0$.[13]

Putting this all together, subscribers in internet-only plans receive utility of $U_i = v_1 + \delta v_2 - p_i$, where the first and second terms capture utility (and quantities) from consuming non-video internet and OTTV applications, respectively. A subscription to the TV service, t, results in video consumption of $q_2^t = v_2$, zero non-video internet usage given the lack of access, and net utility equal to $U_t = v_2 - p_t$. Bundle subscribers consume quantities of video and non-video internet up to their satiation levels and receive utility equal to $U_b = v_1 + v_2 - p_b$. Finally, if the consumer selects the outside option, 0, quantities are zero for both services and utility is zero.

The ISP Profits and Costs

The ISP's profit from serving the market depends on the number of subscribers to each plan, the quantities they select, and the costs of providing these services. For simplicity, we assume that the ISP's costs depend only on the quantity of internet content it transmits; all other costs are zero. This means that we abstract-away from costs such as affiliate or retransmission fees paid to content firms for individual TV subscribers, or the fixed costs of operating the ISP's network.[14]

The ISP's internet-related costs increase with the bytes transmitted through its

[12] This structure may arise if conventional TV carries v_2 shows that each yield utility of one, while all other shows yield a utility of zero.

[13] This assumption represents the best-case/least-cost outcome for the ISP and strengthens incentives to steer consumers to the bundle, but the assumption does not qualitatively change any of the model's predictions.

[14] We believe that our model's qualitative results would not change if we were to include positive per-subscriber costs for TV service. See additional discussion below.

network and therefore are increasing in total usage, which is a function of the number of users and usage (and usage type) by each user. These costs capture the ISP's need to maintain a network that must grow with total usage, in order to avoid congestion, content interruptions, or slowdowns during times of high total usage. We assume that the firm's transmission costs are given by a parameter, γ, times the gigabytes, g, required to transmit the quantities q_1 and q_2^i. We assume that one unit of non-video internet content requires the transmission of one gigabyte, so $q_1 = g$. We further assume that consumption of video content q_2^i requires βg gigabytes, with $\beta > 1$. This captures the greater bandwidth and immediacy needs to transmit video. Consumers' preferences and their choices, given the firm's prices, imply a mapping from tastes to quantities of internet usage, so we write a consumer's internet usage as a function of v. Without restrictions on usage, an internet-only subscriber uses $g_i(v) = v_1 + \beta\delta v_2$ internet units, while a bundle subscriber uses $g_b(v) = v_1$.

Combining consumers' choices with the firm's cost structure, the ISP's profit function is

$$\pi = \int\limits_{v \in S_t} p_t dv + \int\limits_{v \in S_i} [p_i - \gamma g_i(v)]\, dv + \int\limits_{v \in S_b} [p_b - \gamma g_b(v)]\, dv.$$

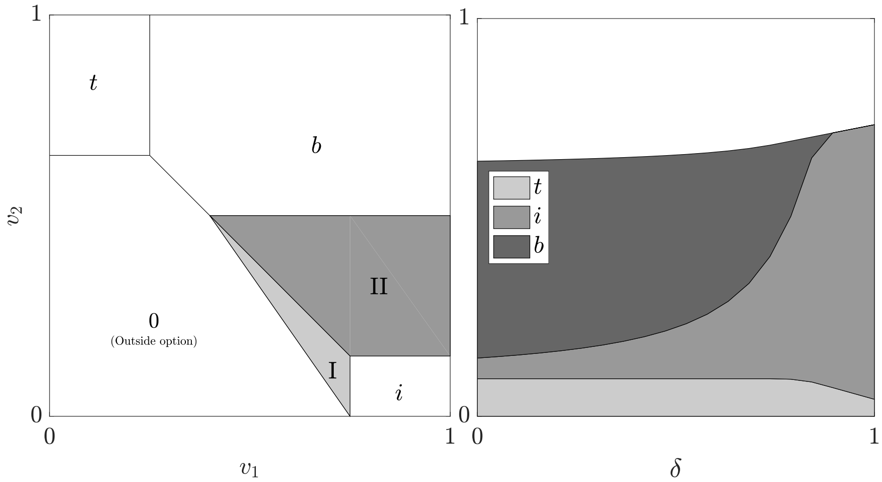
The terms S_t, S_i, and S_b are the sets of consumers who choose internet, TV, and the bundle, respectively.

3.2 Consumer Choice

We now turn to look at the choices consumers make in this setup. In Panel (a) of Figure 3 we present choices different consumers make for a fixed set of prices. When video can only be consumed through TV (i.e., $\delta = 0$), consumers in the areas labeled '0' and 'I' select the outside option, and those in areas 'b' and 'II' select the bundle. Consumers in areas i and t select the stand-alone internet and TV subscription plans. The split is intuitive: consumers with low valuations of both products choose the outside option. Consumers with high valuations for both products choose the bundle, and consumers with high valuation for one service and not the other choose the plan with just one service. As in the textbook bundling model, the exact boundaries between the different choices depend on the prices of the various options.

We next consider the effect of OTTV becoming more attractive (i.e., the effect of an increase in δ) on choices. In Panel (a) we show the effect of δ increasing to 0.7, holding prices fixed at the optimal level for $\delta = 0$ and $\gamma = 0.2$. Two types of consumers change their choices. First, some consumers (in area I) who did not purchase, despite moderately high valuation for internet or video, will now subscribe to i because it

Figure 3: *Consumer Response to Changes in δ*



(a) Substitution (b) Market Shares

Notes: These figures illustrate consumer choices for different levels of δ, holding prices fixed. In panel (a) we present consumer choices for δ equal to 0 and 0.7 holding prices fixed at $(p_i, p_t, p_b) = (0.75, 0.65, 0.9)$, which are the profit-maximizing prices for $\delta = 0$ and $\gamma = 0.2$. In panel (b), we present market shares when δ increases from 0 to 1 and prices are fixed at $(p_i, p_t, p_b) = (0.75, 0.65, 0.9)$.

became more attractive. These new consumers can increase the ISP's profit and are one reason the ISP has an incentive to encourage OTTV. Second, some consumers (in area II) decide to "cut the cord." These consumers initially choose a bundle, but have relatively low video entertainment tastes among bundle subscribers. As δ increases, they prefer stand-alone internet service because they can consume video over-the-top using the internet service. The cord cutting by these consumers diminishes the ISP's revenue, since the bundle price is higher than the internet-only price, and increases the ISP's costs, since supplying video over the internet is costly to the ISP.[15]

These two groups of consumers have opposite effects on the ISP profits, and represent the basic tradeoff the ISP faces: stronger OTTV makes the internet service more valuable but also competes with the TV service. In principle, which effect dominates depends on, among other things, the distribution of tastes. In Panel (b) of Figure 3 we show the effect when tastes are uniformly distributed. In the figure, we plot market shares for each plan at different values of δ, holding prices fixed. The share of internet-only plans, i, grows monotonically in δ, and this largely comes from a reduction in the bundle market share, which is completely eliminated around $\delta = 0.85$. When OTTV is sufficiently beneficial, some consumers even convert their t subscriptions to i, as i offers services very similar to the original bundle.

[15]The ISP will lose profit on these consumers even with a positive cost per TV subscriber, as long there is a positive margin on the TV part of the bundle (specifically, the difference between the bundle price and the internet-only price is greater than the per TV subscriber cost).

Under our distributional and cost assumptions, OTTV improving, holding prices fixed, leads to a reduction in the ISP profits. Many consumers "cut the cord" and trade a more expensive subscription for one with a lower price. This reduces the ISP revenue and increases its streaming costs from video usage that was previously delivered at no marginal cost. The modest increase in total subscriptions is not enough to make up for the decrease in profit from reduced bundle subscriptions.

3.3 ISP Pricing Strategies

In the previous section we showed that, in our setup, an improvement in OTTV can lead to "cord cutting" and a loss in ISP profits, holding prices fixed. Of course, in equilibrium the ISP can and will respond. In this section we study some possible responses, including changing the relative prices of products, limits on internet usage, and tiered pricing of internet usage. We focus on these strategies because they share central elements with the ISP actions we see in the data. Our discussion in this section takes δ as fixed, but in the following section we consider the ISP's incentive to increase or decrease δ, which it could do by promoting or restricting access to OTTV.

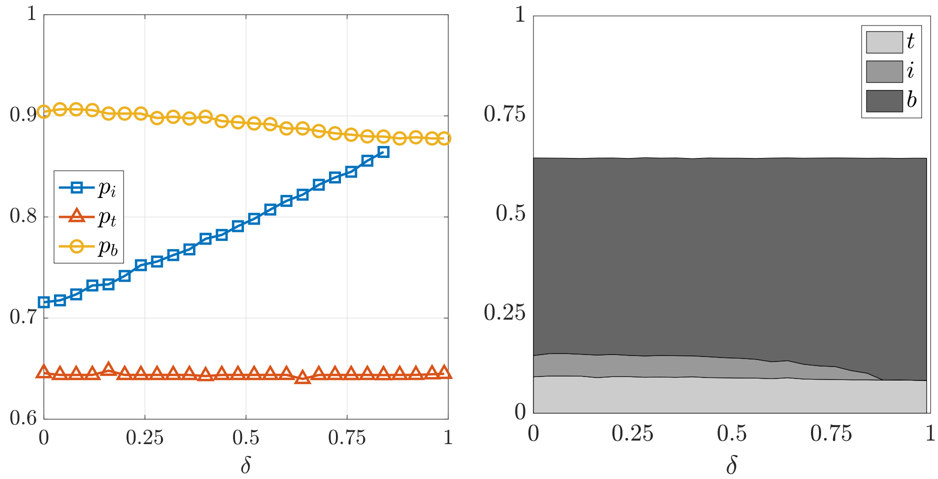
Subscription Prices and Bundle Discounts

In Figure 4 we illustrate the effects of allowing the ISP to set profit-maximizing bundling prices for different values of δ. In Panel (a) we display the prices, while in Panel (b) we present the market shares of t, i, and b given these prices. By comparing Figures 3 and 4, we can see clearly the steering effect prices can have. Greater values of δ drive the ISP to set greater values of p_i and greater bundle discounts, i.e. the difference between p_b and $p_i + p_t$. By increasing the price of the internet-only product, the ISP can push back and reverse the effect of an increase in δ on cord cutting. As we show in Panel (b) of Figure 4, with optimal mixed bundling prices the share of the internet-only plan actually decreases. The steering effects are especially strong for $\delta > 0.8$, when the optimal pricing sets $p_b = p_i$ and therefore the share of internet-only subscriptions goes to zero.[16] With the pricing instruments available in this case, the cost impact of δ is greater than ISP's opportunity to profit from the increased value of internet-only subscription plans, so it effectively shuts down this plan.

In the particular setting we evaluate above, we find that optimizing prices mitigates the decline in profits but does not eliminate it completely. The ISP's profits decrease mildly in δ. We return to this point below.

[16]Under our assumption that bundle subscribers receive all of their video entertainment via the TV subscription, the elimination of i also eliminates OTTV usage. In a more realistic model, bundle subscribers would consume video through both TV and the internet, and OTTV consumption would not be eliminated.

Figure 4: *Optimal Prices for Varying Values of δ*



(a) Prices (b) Market Shares

Notes: Panel (a) displays the ISP's profit-maximizing prices as δ varies from 0 to 1. Panel (b) provides the market shares resulting from these prices. We compute prices and shares numerically using the assumptions described in the text.

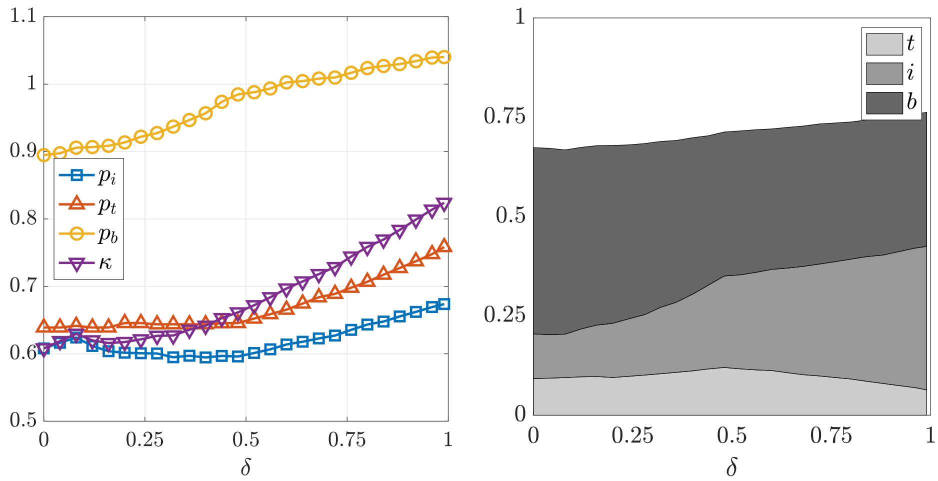
Usage Limits

As we showed in the discussion above, firms may find it optimal to set prices such that the internet-only product is basically eliminated. However, if firms are permitted to use more sophisticated strategies, their incentives to steer consumers into the bundle may be reduced. One possible strategy is to charge consumers an access or subscription fee in return for a usage allowance which puts a strict cap on internet usage. This is a simplified version of the three-part tariff we see in our data, where the consumer pays an overage charge when he exceeds the allowance. With our assumption of marginal utility equal to either one or zero, depending on the quantity consumed, an optimally-set overage charge is equal to one, and ISP's only interesting strategic choice is the usage allowance.

Let κ denote the usage allowance in GBs. The effect of the allowance is straightforward: as long as it is set low enough, the allowance will truncate the usage of any consumer with $v_1 > \kappa$, regardless of whether they purchase a bundle or the internet-only plan. This allows the ISP to keep cost down even as δ increases, namely, the ISP can limit how much consumers can increase their use of streaming video when δ improves.

In Figure 5 we illustrate the consequences of allowing the ISP to set κ. In Panel (a) we illustrate optimal prices and allowances for a range of δ values, and in Panel (b) we present the resulting market shares. The allowance has a significant impact on the ISP's choices of subscription plan prices and therefore market shares. The internet and bundle prices both increase gradually with δ, and internet-only subscriptions eventually

Figure 5: *Optimal Prices and Allowance for Varying Values of δ*



(a) Prices and Allowance (b) Market Shares

Notes: Panel (a) displays the ISP's profit-maximizing prices and allowance when the ISP sets a usage allowance, as δ varies from 0 to 1. Panel (b) summarizes the change in market shares at each optimal price combination.

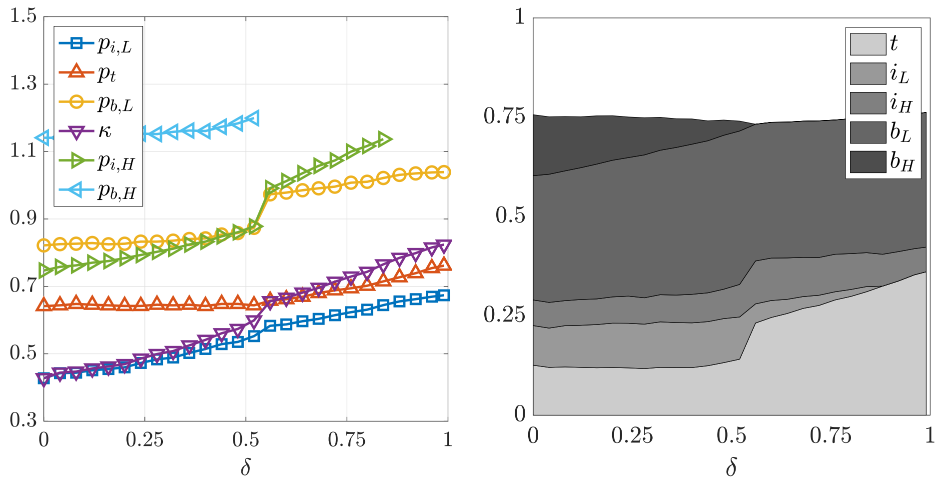
overtake the bundle as the most popular option. Overall, the ISP serves a greater share of the full consumer population as δ rises. The usage cap, which is just above p_i for low values of δ, increases more quickly with δ than p_i, which effectively loosens the ISP's restrictions on internet usage as streaming video improves. (Some i subscribers with large v_1 and small v_2 use no OTTV, while others consume both internet services and streaming video.) Thus, the introduction of the allowance can permit the ISP to balance providing access to more consumers while simultaneously steering customers with greater video demand toward the bundle, where they can receive video at lower cost to the ISP. The presence of a usage cap can actually lead the ISP to permit more internet and OTTV usage than it would if usage caps were prohibited, because the cap allows the ISP to influence usage choice more selectively.

The opportunity to set a usage cap can lead to the ISP's profit increasing in δ. The firm receives the revenue benefits of increased prices (due to increased value to consumers) from consumers who would use a low or moderate amount of OTTV even without a cap, plus it can limit the OTTV-related costs of internet-only consumers who would use larger quantities of streaming video in the absence of a cap.

Usage Tiers

In addition to using base prices (p_t, p_i, p_b) and allowances (κ) to steer consumers among packages, ISPs also often separate their internet services into tiers that vary in allowances, overage prices, or connectivity speeds. We consider the effect of the ISP introducing a "low usage" internet tier with a usage allowance κ and a "high usage"

Figure 6: *Optimal Tiered Prices and Allowance for Varying Values of* δ



(a) Prices and Allowance (b) Market Shares

Notes: Panel (a) depicts the ISP's optimal tier prices and usage allowance as δ varies from 0 to 1. Panel (b) summarizes the change in market shares at each optimal price and allowance combination.

tier with no usage limit. Consumers can select one of these internet tiers alone or as part of a bundle with conventional TV. For simplicity, and consistent with industry practice, we assume that the difference (i.e. discount) between the bundle price and the sum of TV and internet prices is the same regardless of which tier a consumer chooses.

When the ISP introduces tiers and allowances to a setting which had neither, several types of consumers are affected in distinct ways. First, some consumers who had internet-only subscriptions will stay with this type of plan, with consumers separating between capped and uncapped tiers based on their valuations of internet content (including OTTV). Second, some internet-only consumers with strong video tastes will switch to a bundle plan, with the internet tier depending on their value of v_1. Finally among initial i subscribers, some will cancel their subscriptions completely because their relatively strong taste for video entertainment and weak taste for non-video internet means that capped internet and bundle subscriptions are worth less than the outside option. Turning to consumers who previously choose a bundle, some with strong internet tastes will opt for the unlimited usage option so that they can consume more content. In the Appendix we provide additional discussion and graphical illustration of these effects.

Next, we consider how the ISP would set prices and tiers for different values of δ. In Figure 6 Panel (a) we provide the ISP's optimal prices and cap values, and in Figure 6 Panel (b) we show the resulting market shares. In this setting, the ISP has several levers for steering consumers' choices, extracting rents, and reducing costs, and as a consequence the ISP's strategy varies qualitatively with δ. For δ values less than about 0.5, the ISP allows prices to increase with δ so that it captures some of the additional value available to consumers through OTTV. (The high-usage bundle's share falls in δ because video usage opportunities remain constant for TV subscribers.) For relatively high values of δ, the ISP's strategy changes, and it raises the high-usage internet price substantially to shrink this plan's market share. When δ is large, the cost of offering unlimited internet usage is too great relative to the premium the ISP can charge consumers for the plan. As the ISP reduces the high-usage internet tier, it raises the low-usage tier's allowance, which accommodates more OTTV usage within this tier. The ISP benefits, on the whole, from steering consumers into the low-usage internet tier where it can recover value from OTTV with an increased price, while also limiting the usage of inframarginal consumers whose OTTV usage choices, if unchecked, would be costly for the ISP.

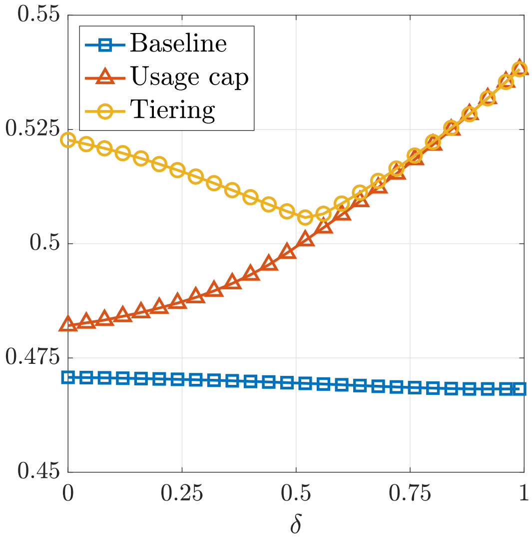
As δ increases from 0 to 1, the ISP's profit first falls in δ and then it rises, with the reversal coinciding with the ISP's qualitative change in pricing strategy. When δ is zero, the ISP benefits strongly from the opportunity to segment consumers by their taste for non-video internet, but once δ increases there are additional costs from uncapped internet-only subscriptions. These costs reduce ISP profit until the firm (largely) turns to steering its internet-only consumers into capped subscriptions, where the ISP's price and profit rise as OTTV improves.

3.4 ISP Incentives to Promote or Restrict OTTV

As we show above, when the OTTV quality improves the ISP faces a tradeoff. On one hand, higher quality OTTV products and services make the internet service more attractive and therefore the ISP has an incentive to promote OTTV. On the other hand, OTTV is a direct substitute for the ISP's TV service, and therefore the ISP might have an incentive to restrict OTTV usage or degrade its quality. In the previous section, we explored what this tradeoff implies for the ISP incentive to steer consumers using various pricing tools. We now explore the ISP's direct incentives to either improve or degrade the quality of OTTV. It is exactly these types of concerns that fuel the Net Neutrality debate. In the context of our model we can study the direct incentives to promote or restrict OTTV by allowing the ISP to impact δ.

In our analysis of the three pricing strategies discussed above – bundle pricing, usage limits, and usage tiers – the ISP's approach to OTTV varies substantially. With bundle pricing, OTTV usage first grows with δ and then it falls as the ISP effectively eliminates its internet-only subscriptions. With usage limits and tiers, by contrast, the ISP allows OTTV usage to grow with δ within significant internet-only market shares. This divergence in OTTV usage occurs because the more "sophisticated"

Figure 7: *Profits by pricing strategy across δ values*



Notes: This figure shows ISP profits when it uses optimal bundle prices, optimal prices and usage cap, and optimal prices and cap with usage tiers.

pricing strategies allow the ISP to capture some of the value generated by OTTV while limiting its effects on the ISP's costs and TV demand. The same logic holds in the results below.

To demonstrate these effects, we plot in Figure 7 the ISP profits for different pricing strategies and different values of δ. These profits correspond to the prices and market shares presented in Figures 4, 5 and 6. As expected, Figure 7 shows that the firm's profit is weakly greater for any δ when it has more instruments in designing a pricing plan. More importantly, the strategies' profit levels vary in whether they increase or decrease in δ. The variation in the slope across strategies comes from differences in the ISP's ability to extract rents versus avoid additional costs when OTTV's quality improves.

The differences in profit slopes and levels across δ values comes from the firm's opportunity to balance a complex set of tradeoffs regarding consumer choices. Our model shows that, even in a simple framework, an ISP's policies toward OTTV will depend on the current quality of streaming video and what pricing tools ISPs may use. ISPs that are restricted from setting overage charges or creating tiered service might often benefit from stifling OTTV access, while ISPs with more pricing tools may encourage OTTV usage. More generally, our model demonstrates that prices and plans offered to consumers are a key component of the Net Neutrality debate; restrictions and promotion of third-party internet content does not just happen at the level of ISP-to-firm negotiations upstream.

4 Households' Responses to UBP

As we mentioned in Section 2, during our sample period the ISP introduced UBP in some of the markets we observe, but not in others. The introduction of UBP, which we describe in detail below, amounts to a change in the price of using the internet. Furthermore, the price effect is different for different consumers based on their usage and current plans.

Our model provides guidance on what empirical outcomes are important for evaluating an ISP's ability to steer consumers, and therefore its incentives to promote or restrict OTTV. One central issue is the degree of substitutability between linear TV and OTTV. We assess this by estimating the elasticity of TV subscriptions with respect to the price of internet usage. We also go deeper by looking at how relatively close substitutes for conventional TV (i.e. Linear OTTV) have a different substitution relationship than other forms of OTTV (e.g. Netflix). Second, an ISP's return from tiered subscription plans is closely related to the surplus consumers may receive from incremental OTTV consumption. This idea is also related to consumer heterogeneity in OTTV demand, which plays a significant role in our theoretical model. In our empirical analysis, we study these issues by estimating consumers' elasticity for upgrading their internet tier. Third, it is important to understand whether OTTV usage is sensitive to caps and premia, and consumers do not just focus their internet usage changes in non-OTTV applications when allowances and tiers are introduced. We investigate this empirically by estimating elasticities of subscription and usage for major OTTV services with respect to the price of internet usage. This builds on the summary statistics in Section 2 that show changes in OTTV usage when consumers cut the cord. As we will show, the data support the broad characteristics of our theoretical model, and therefore our conclusions about ISPs' incentives to restrict or encourage OTTV usage.

4.1 The Introduction of UBP

We observe one "treated" market where UBP was introduced and several additional "control" markets where the introduction did not happen during the sample period. The ISP's introduction of UBP came in two phases. First, the ISP announced that UBP would be arriving within a few months, and it provided households with information about how their monthly usage compared to the data allowance within their current internet tier. During this phase, which we call the "announcement period," households were not billed if their usage exceeded their tier's allowance. In the next phase, which we call the "treatment period," the ISP assessed overage charges on households that exceeded their allowances. Immediately prior to the announcement and treatment periods, which each last a few months in our sample, we observe two months of activity (a "pre-policy period") in which the treated and control markets are subject to the same pricing policies by the ISP. Other than the introduction of UBP, the ISP's internet tiers were identical across markets in our sample. Throughout the full sample period, control markets without UBP had no announcements or policy changes linked to households' internet usage. Across all markets we observe, competitors' subscription offerings did not change meaningfully during the sample period, including in response to the UBP policy's introduction.

4.2 Direct Evidence on Households' Response to UBP

We now describe UBP's impact on households' subscription choices and overall internet usage. We do this by looking at cross-market differences in how subscriptions and usage changed during the sample period. This provides a direct look at the quantities selected by consumers; in the next section we consider the role of price impacts by calculating elasticities.

We begin this analysis by focusing on changes to ISP subscriptions. In all markets, there is a regular flow of consumers who update their internet tiers and TV subscriptions. Some of these updates are due to factors outside of our model, like changes in household composition or seasonal programming, while other subscription updates may be due to UBP's introduction. In our initial analysis, we ask whether consumers' flows across subscription options was significantly different between the treatment and control markets.

We first focus on consumers who were internet-only throughout the pre-policy period. These consumers had the opportunity to add TV, upgrade their internet tier, or both between the start of the announcement period and the end of the sample. We compute transition frequencies using a multinomial logit model, which allows us to compute these frequencies for several different subsets of the consumer population, based on certain consumer characteristics we include in the model. We provide the model's specification and parameter estimates in Appendix Table 8, and we report the predicted probabilities in Table 2. In the first set of Table 2's rows, where we consider the transitions of all households in aggregate, we report that households in exposed to UBP were more likely to add TV alone, upgrade their internet tier alone, or take both actions together. Our theoretical model predicts that consumers could alter their subscriptions in these ways, in addition to some consumers making no change and others potentially dropping their service altogether. (Due to data limitations we do not study differences across markets in ISP quit rates.)

The theoretical model also suggests that internet-only consumers with different characteristics (i.e. strong tastes for video or non-video content) favor particular options for subscription changes. We take a closer look at these predictions by exploring how consumers with different pre-policy usage and subscription changes make different choices from the treated population at large. We first look at "heavy" users, which we define with the dummy variable $Heavy = 1$ for a household that has an average pre-policy usage greater than half of the (eventual) allowance. In Table 2 we report that treated households with $Heavy = 1$ were slightly less likely to add TV alone, but they were significantly more likely to upgrade their internet tier, both alone and while adding TV. These results, again, are largely consistent with our model's predictions, which suggest that consumers with relatively high values of v_1 will upgrade their internet tier, and if v_2 is also high the consumer will add TV as well. (Overall, TV subscription changes is approximately zero within this group.)

We next take a closer look at internet-only households with strong tastes for video entertainment. We create a pair of dummy variables, *Netflix* and *LinOTTV*, which indicate whether a household actively uses Netflix or one or more Linear OTTV services (i.e. Sling TV or Hulu), respectively, and we interact each variable with *Heavy*.[17] In Table 2 we show that households with $Heavy \times LinOTTV = 1$ are more likely add TV in the markets where UBP was introduced; this difference is entirely concentrated among households who also upgrade their internet tier. The impact of UBP is generally weaker for internet-only households with $Heavy \times Netflix = 1$, which is consistent with the intuition that linear OTTV and convention TV are closer substitutes than Netflix and TV.

We provide a parallel analysis of households who subscribed to the bundle at the end of the pre-policy period, and therefore could drop TV, upgrade internet, or both. Although our theoretical model does not directly address these flows in the context of new UBP and tiers, the movement of consumers into internet-only subscriptions is a central issue in telecommunications markets. We report multinomial logit transition frequencies in Table 3, with the full specification and parameter estimates in Appendix Table 9. In this analysis we omit the effects that capture linear OTTV subscribers during the pre-policy period.[18] Our estimates of the overall treatment effect, provided in the rows labeled "All households," show that treated households were 15% less likely to drop their TV subscriptions without changing their internet tier. In terms of Section 2's model, UBP's effect is to reduce the value to consumers of moving across

[17] We classify a household as an "active" user if usage is above certain thresholds in total GBs and days with positive usage per billing cycle. This helps us avoid misclassification due to, for example, short-term visitors to a household who may use their hosts' WiFi to access OTTV services to which the hosts do not subscribe.

[18] Fairly few households subscribed to linear OTTV and conventional TV simultaneously, and some of those who did may not have viewed the portfolio as a long-term choice, but were instead experimenting with linear OTTV or in the midst of switching away from conventional OTTV.While linear OTTV provides some access and content options unavailable through conventional TV, the services were very similar during our sample period.

Table 2: Switching probabilities for internet-only subscribers

Population group		Add TV	Upgrade Tier	Add and Upgrade
All households	Control	2.62	3.05	0.41
	Treatment	3.06	7.00	0.56
	Difference	0.44	3.95	0.15
	(SE)	(0.19)	(0.28)	(0.09)
$Heavy = 1$	Control	2.95	4.08	0.52
	Treatment	2.33	17.04	0.98
	Difference	-0.62	12.96	0.47
	(SE)	(0.32)	(0.75)	(0.20)
$Heavy \times LinOTTV = 1$	Control	3.57	4.03	0.60
	Treatment	3.47	21.81	1.72
	Difference	-0.11	17.78	1.12
	(SE)	(0.70)	(1.57)	(0.49)
$Heavy \times Netflix = 1$	Control	3.25	4.11	0.52
	Treatment	2.55	17.34	1.08
	Difference	-0.70	13.23	0.56
	(SE)	(0.36)	(0.83)	(0.23)

Notes: This table provides the shares of initially internet-only consumers who Add TV alone, Upgrade Tier alone, or both Add TV and Upgrade Tier. We report the shares separately for the Treated (i.e. with UBP) and Control (i.e. no UBP) markets. The “Population group” identifies the subset of the sample population considered within a panel on the table.

the bundle/internet-only margin. Internet tier upgrades (alone) were almost twice as likely in the treated market. In the theoretical model, this is generated by demand for non-video internet by consumers with high v_1, but in the data it is likely a combination of video and non-video internet usage. Finally, more households in the treated market dropped TV and upgraded internet jointly, but the mass of consumers in this outcome is smaller than those steered away from cord-cutting alone. Overall, UBP appears to steer consumers into high-priced usage tiers while generating for the ISP a small reduction in the cord-cutting rate.

UBP's impacts are generally larger among bundle subscribers with $Heavy = 1$. While cord-cutting alone was about 30% less common among heavy internet users in the treated market, there is a slight increase in total cord-cutting due to a greater frequency of this action joint with tier upgrading. This result could be due to the internet content tastes of heavy-usage consumers on the margin between the bundle and internet-only. Finally, the choices of bundled households with $Heavy \times Netflix = 1$ are very similar to heavy-usage households without Netflix subscriptions.

Table 3: Treatment effect on bundle subscriber transition probabilities

Population group		Drop TV	Upgrade Tier	Drop and Upgrade
All households	Control	2.23	3.68	0.27
	Treatment	1.87	6.54	0.53
	Difference	-0.36	2.86	0.26
	(SE)	(0.09)	(0.15)	(0.05)
$Heavy = 1$	Control	3.25	5.08	0.55
	Treatment	2.29	18.61	2.11
	Difference	-0.96	13.53	1.55
	(SE)	(0.28)	(0.70)	(0.26)
$Heavy \times Netflix = 1$	Control	3.25	4.11	0.52
	Treatment	2.55	17.34	1.08
	Difference	-0.70	13.23	0.56
	(SE)	(0.36)	(0.83)	(0.23)

Notes: This table provides the shares of initially bundle consumers who Drop TV alone, Upgrade Tier alone, or both Drop TV and Upgrade Tier. We report the shares separately for the Treated (i.e. with UBP) and Control (i.e. no UBP) markets. The "Population group" identifies the subset of the sample population considered within a panel on the table.

In addition to describing transitions in ISP subscriptions, we show in Table 4 how internet usage changed with UBP's introduction. Following the analysis above, we divide households by whether they live in a market where UBP was introduced and whether $Heavy = 1$; for simplicity, we aggregate the choices across households with internet-only and bundle subscriptions. Changes in usage vary with the endogenous choice of whether to upgrade internet tier, and for illustrative purposes we divide

Table 4: internet Usage Growth

	Upgrade	No upgrade
$Heavy = 0$		
Control	52.1	30.7
Treated	50.7	19.6
$Heavy = 1$		
Control	79.5	28.6
Treated	60.0	-16.4

Notes: We report the average level change in monthly consumption (measured in gigabytes) between the pre-policy period and the treatment period for subscribers of different types. A subscriber type is defined by treatment exposure, whether the subscriber was a heavy user in the pre-policy period, and whether the subscriber upgraded their internet tier between the pre-policy period and the end of the sample.

households by their upgrade decision. Per-household usage increased by less in the treated market, regardless of whether a household upgraded its tier or had $Heavy = 1$. Usage by households with $Heavy = 0$ grew similarly among households that upgraded their internet tier, but lower-usage treated households that did not upgrade their tier increased their usage by about two-thirds the amount in control markets. Some households in this group may have reduced their usage growth in order to avoid overage charges from exceeding their usage allowances. Among users with $Heavy = 1$, there are greater differences between growth levels in the treated and control markets. In addition, we observe large differences in usage growth between the consumers who opted to upgrade their tier versus those who did not. Notably, we observe negative usage growth among (initially) heavy-usage treated households who did not upgrade. Considering the general growth in internet usage during recent years, any population with a usage reduction stands out from widespread trends.

Our initial results on UBP's effects show some significant changes in household behavior. As described in our theoretical model, when the ISP increases the price of internet usage, fewer consumers opt for internet-only subscriptions and some upgrade their internet usage tier. There are notable differences in these impacts across consumers with difference internet usage intensities and OTTV subscriptions, which suggests heterogeneity in both the impact of UBP and the value that consumers receive from their internet subscriptions. In addition to impacts on plan-level subscriptions, consumers' total quantity of internet usage is affected by UBP's introduction.

4.3 Demand Elasticities

In this section we use UBP's introduction to compute various demand elasticities for the full population and some specific consumer groups. Specifically, we estimate elasticities for subscriptions and usage, which one might view as extensive and intensive margins. The elasticities cover subscriptions and usage for both ISP and OTTV plans. Our elasticity calculations combine the household-level responses to UBP's introduction, summarized in the previous section, with the individual households' price exposure due to UBP. We exploit both cross-market and within-market price variation. Treated households can be compared to control households that were not exposed to UBP, and the three-part pricing structure of UBP implies that treated households vary in their price exposure based on their proximity to the usage allowance for their initial tier.

Responses to price changes along nonlinear price schedules can be difficult to specify and compute. In our situation, this is compounded by the fact that household internet usage was growing rapidly during the sample period. In the control markets, some households had pre-policy usage levels below their tier's threshold, and then usage grew to exceed the threshold during the treatment period.[19] As control households not exposed to UBP, these individuals would have paid no overage charges. In the treated market, similar households may have adjusted their usage (and its growth) or updated their subscription plan so that they did not receive overage charges either. Nevertheless, in this example the treated households altered their choices in response to (anticipated) overage charges.

In order to capture UBP's price impact, we use the usage behavior of control households to compute expected prices to treated households from various actions. (We refer to "expected prices" because we treat usage growth as probabilistic based on the distribution of growth in the control markets.) In particular, we predict usage levels within different subscription options for treated households, under the assumption that no UBP is in place, and then we compute the associated overage charges. For example, this means that an internet-only household in a low-allowance tier might face a relatively high usage charge if there is no change in tier or TV subscription, but the expected usage charge is smaller if the household upgrades to a higher-allowance tier. Let $p_h(s)$ be the expected overage charge for household h when it selects subscription option s. We think of s as a vector of subscriptions, including both ISP and OTTV services. All households in the control markets have $p_h(s) = 0$. Within the treated market, households' $p_h(s)$ values vary because different households' likelihood of exceeding a usage allowance varies with pre-policy internet usage and subscription choices. See the Appendix for additional details about calculating $p_h(s)$.

ELASTICITY CALCULATION DETAILS AND RESULTS TO BE ADDED.

[19] In describing our approach, it is useful to think of all internet tiers, whether offered in the control or treatment markets, as having usage allowances (which are the same across markets), but only in the treated market does exceeding an allowance trigger a charge.

5 Conclusions

We study the impact of increasingly popular online video services on the telecommunications industry. OTTV represents an opportunity for ISPs in that streaming video increases the demand for internet subscription services, but the new applications also present several important challenges. OTTV improvements reduce demand for ISPs' television services, and delivering internet content can substantially increase ISPs' costs. The firms have responded with nonlinear pricing strategies to steer consumers across subscription options and possibly curtail internet and OTTV usage.

We provide an illustrative model that describes the some of the central incentives behind ISPs' prices, and we use panel data on household-level subscriptions and internet usage to evaluate the model's predictions. Our model shows that bundle discounts, usage limits, and usage tiers are valuable instruments for steering consumers. In our empirical analysis, we find that telecommunications firms successfully steer consumers to higher-priced subscriptions by using nonlinear pricing for internet services. In addition to changes in consumers' subscriptions, steering curtails growth in internet usage – in some cases reducing usage despite widespread trends toward positive growth. These general outcomes, along with more nuanced results regarding the heterogeneity in steering's impact, have a number of important implications for ongoing policy debates.

Steering's impact is relevant for antitrust policy related to the telecommunications industry. In particular, evaluation of mergers between content and distribution firms present a number of challenges. First, market boundaries may be difficult for regulators and antitrust authorities to identify because little evidence exists on consumers' willingness to substitute across conventional TV, streaming video, and other non-video internet applications. Our results show that consumers are willing to substitute among online entertainment sources and with conventional TV. Specifically, we find that cord-cutters increase their usage of most online applications after dropping an ISP's TV service, and these increases are roughly proportional to usage levels prior to the subscription change.[20] Thus, telecommunications antitrust analysis might consider broad market definitions that encompass many forms of digital entertainment (e.g., Facebook and NBC compete for a consumer's time), as well as the central role of ISPs in shaping how content is distributed and surplus is allocated.

Second, antitrust authorities need to assess how existing or new vertical relationships may affect a ISPs' incentives to introduce restrictive cross-licensing agreements or use price instruments to favor its own content over competitors'. The impact of

[20] Consumers who are steered into the bundle appear to reduce only their OTTV usage, but it is difficult to untangle the policy's effect from general trends toward greater internet usage in every type of application.

these strategies depends on consumers' sensitivity to steering strategies, which we show can be significant. An ISP that is vertically integrated with a content-producing firm may foreclose some content from availability to consumers via a competing ISP. A price-based steering strategy with similar effects is "zero rating," which favors certain content by not counting its usage against a monthly allowance. Our elasticity estimates show that even blunt mechanisms like usage-based pricing can have important allocative consequences among consumers and various firms. Firms may perceive even greater benefits of zero rating than UBP because a targeted mechanism is likely to be more profitable.

More broadly, our results are also relevant for the Net Neutrality debate, in which empirical evidence is rare. Net Neutrality's repeal provides ISPs more latitude to discriminate across types of internet traffic. While we do not observe source-specific discrimination in our analysis, our results are informative about ISPs' incentives to discriminate when they have the opportunity. For example, we find that usage-based pricing's primary impact is in inducing consumers to upgrade their internet tiers and continuing using their preferred online applications (e.g., Netflix), although there are some exceptions like linear OTTV, where bundle subscriptions shift significantly. If an ISP can successfully use tier premiums to extract some of the rents associated with OTTV innovations, it may not seek more targeted mechanisms to foreclose or diminish the attractiveness of OTTV. These incentives may change, however, as firms diversify and vertically integrate into media production, so more research is needed in this area.

There are several issues that our model and empirical results do not address, and that we leave for future research. While our model provides a useful framework for formalizing the steering incentives of ISPs, a richer specification is required to quantify the welfare implications of steering. Similarly, the model makes simplifying assumptions on the interaction between firms, for example competitive OTTV supply. Given the increasingly complex relationships between content providers and ISPs, and the evolving regulatory and antitrust environment, modeling and evaluating these policy issues is a fruitful area for future research.

References

Armstrong, Mark (2006). "Competition in Two-Sided Markets." *RAND Journal of Economics*, 37(3): 668–691.

Armstrong, Mark (2013). "A More General Theory of Commodity Bundling." *Journal of Economic Theory*, 148(2): 448–472.

Barwick, Panle Jia, Parag A. Pathak and Maisy Wong (2017). "Conflicts of Interest and Steering in Residential Brokerage." *American Economic Journal: Applied Economics*, 9(3): 191–222.

Bourreau, Marc, Frago Kourandi and Tommaso Valletti (2015). "Net Neutrality with Competing Internet Platforms." *Journal of Industrial Economics*, 63(1): 30–73.

Choi, Jay Pil, Doh-Shin Jeon and Byung-Cheol Kim (2015). "Network Neutrality, Business Models, and Internet Interconnection." *American Economic Journal: Microeconomics*, 7(3): 104–141.

Choi, Jay Pil and Byung-Cheol Kim (2010). "Net Neutrality and Investment Incentives." *RAND Journal of Economics*, 41(3): 446–471.

Chu, Chenghuan, Phillip Leslie and Alan Sorensen (2011). "The Welfare Effects of Vertical Integration in Multichannel Television Markets." *American Economic Review*, 101(1): 263–303.

Crawford, Greg, Robin Lee, Mike Whinston and Ali Yurukoglu (2017). "The Welfare Effects of Vertical Integration in Multichannel Television Markets." *Working Paper.*

Crawford, Gregory and Matthew Shum (2007). "Monopoly Quality Degradation and Regulation in Cable Television." *Journal of Law and Economics*, 50(1): 181–219.

Crawford, Gregory and Matthew Shum (2015). "The Welfare Effects of Monopoly Quality Choice: Evidence From Cable Television Markets." *Working Paper.*

Crawford, Gregory and Ali Yurukoglu (2012). "The Welfare Effects of Bundling in Multichannel Television Markets." *American Economic Review*, 102(2): 643–685.

Dutz, Mark, Jonathan Orszag and Robert Willig (2009). "The Substantial Consumber Benefits of Broadband Connectivity for US Households." *Internet Intervention Alliance Working Paper.*

Economides, Nicholas and Benjamin Hermalin (2012). "The Economics of Network Neutrality." *The RAND Journal of Economics*, 43(4): 602–629.

Economides, Nicholas and Benjamin Hermalin (2015). "The Strategic Use of Download Limits by a Monopoly Platform." *The RAND Journal of Economics*, 46(2): 297–327.

Economides, Nicholas and Joacim Tag (2012). "Network Neutrality on the Internet: A Two-Sided Market Analysis." *Information Economics and Policy*, 24(2): 91–104.

Economides, Nicholas and Joacim Tag (2016). "Internet Regulation, Two-Sided Pricing, and Sponsored Data." *Working Paper*.

Edell, Richard and Pravin Varaiya (2002). *Providing Internet Access: What We Learn from INDEX*, volume Broadband: Should We Regulate High-Speed Internet Access? Brookings Institution.

Gans, Joshua (2015). "Weak Versus Strong Net Neutrality." *Journal of Regulatory Economics*, 47(2): 183–200.

Gentzkow, Matthew (2007). "Valuing New Goods in a Model with Complementarity: Online Newspapers." *American Economic Review*, 97(3): 713–744.

Goetz, Daniel (2016). "Competition and Dynamic Bargaining in the Broadband Industry." *Princeton University Working Paper*.

Goolsbee, Austan and Peter Klenow (2006). "Valuing Products by the Time Spent Using Them: An Application to the Internet." *American Economic Review P&P*, 96(2): 108–113.

Greenstein, Shane and Ryan McDevitt (2011). "The Broadband Bonus: Estimating Broadband Internet's Economic Value." *Telecommunications Policy*, 35(7): 617–632.

Greenstein, Shane, Martin Peitz and Tommaso Valletti (2016). "Net Neutrality: A Fast Lane to Understanding the Tradeoffs." *Journal of Economic Perspectives*, 30(2): 127–150.

Grubb, Michael (2015). "Consumer Inattention and Bill-Shock Regulation." *Review of Economic Studies*, 82(1): 219–257.

Grubb, Michael and Matthew Osborne (2015). "Cellular Service Demand: Biased Beliefs, Learning, and Bill Shock." *American Economic Review*, 105(1): 234–271.

Hagemann, Garrett (2017). "Upstream Quantity Discounts and Double Marginalization in the New York Liquor Market." *Working Paper*.

Hitte, Loran and Prasanna Tambe (2007). "Broadband Adoption and Content Consumption." *Information Economics and Policy*, 74(6): 1637–1673.

Ho, Kate and Robin Lee (2017). "Equilibrium Insurer-Provider Networks: Bargaining and Exclusion in Health Care Markets." *Working Paper*.

Lambrecht, Anja, Katja Seim and Bernd Skiera (2007). "Does Uncertainty Matter? Consumer Behavior Under Three-Part Tariffs." *Marketing Science*, 26(5): 698–710.

Lee, Robin and Tim Wu (2009). "Subsidizing Creativity through Network Design: Zero-Pricing and Net Neutrality." *Journal of Economics Perspectives*, 23(3): 61–76.

Liebman, Eli (2017). "Bargaining in Markets with Exclusion: An Analysis of Health Insurance Networks." *Working Paper*.

Malone, Jacob, Aviv Nevo and Jonathan Williams (2016). "A Snapshot of the Current State of Residential Broadband Networks." *NET Institute Working Paper No. 15-06*.

Malone, Jacob, John Turner and Jonathan Williams (2014). "Do Three-Part Tariffs Improve Efficiency in Residential Broadband Networks?" *Telecommunications Policy*, 38(11): 1035–1045.

McManus, Brian (2007). "Nonlinear Pricing in an Oligopoly Market: the Case of Specialty Coffee." *RAND Journal of Economics*, 38: 512–532.

Miravete, Eugenio (2003). "Choosing the Wrong Calling Plan? Ignorance and Learning." *American Economic Review*, 93(1): 297–310.

Mussa, Michael and Sherwin Rosen (1978). "Monopoly and Product Quality." *Journal of Economic Theory*, 18(2): 301–317.

Nevo, Aviv, John Turner and Jonathan Williams (2016). "Usage-Based Pricing and Demand for Residential Broadband." *Econometrica*, 84(2): 411–443.

Raval, Devesh and Ted Rosenbaum (2017). "Payer Steering and Patient Welfare: Evidence from Medicaid." *Working Paper*.

Reggiani, Carlo and Tommaso Valletti (2016). "Net Neutrality and Innovation at the Core and at the Edge." *International Journal of Industrial Organization*, 45(1): 16–27.

Rosston, Gregory, Scott Savage and Bradley Wimmer (2013). "Effect of Network Unbundling on Retail Price: Evidence from the Telecommunications Act of 1996." *Journal of Law and Economics*, 56(2): 487–519.

Sidak, Gregory (2006). "A Consumer-Welfare Approach to Network Neutrality Regulation of the Internet." *Journal of Competition Law & Economics*, 2(3): 349–474.

Tudon, Jose (2018). "Congestion v. Content Provision in Net Neutrality: The Case of Amazon's Twitch.tv." *Working Paper*.

Varian, Hal (2002). *The Demand for Bandwidth: Evidence from the INDEX Experiment*, volume Broadband: Should We Regulate High-Speed Internet Access? Brookings Institution.

Wu, Tim (2003). "Network Neutrality, Broadband Discrimination." *Journal of Telecommunications and High Technology Law*, 1(2): 141–178.

6 Appendix

6.1 Additional Descriptive Statistics on Usage Patterns

Table 5: Description of internet Traffic Groups

Group	*Description (Examples)*	*% of All Usage*
Admin	System administrative tasks (STUN, ICMP)	1.19
Backup	Online storage (Dropbox, SkyDrive)	0.58
Browsing	General web browsing (HTTP, Facebook)	26.70
CDN	Content delivery networks (Akamai, Level3)	2.95
Gaming	Online gaming (Xbox Live, Clash of Clans)	3.06
Music	Streaming music services (Spotify, Pandora)	3.40
Sharing	File sharing protocols (BitTorrent, FTP)	0.20
Streaming	Generic media streams (RTMP, Plex)	6.26
Tunnel	Security and remote access (SSH, ESP)	0.07
Video	Video streaming services (Netflix, YouTube)	55.47
Other	Anything not included in above groups	0.13

Table 6: Daily Usage Statistics by DPI Group, 2015

	count	mean	std	min	25%	50%	75%	95%	max
Tunnel	119,878,359	0.00	0.20	0.00	0.00	0.00	0.00	0.00	360.01
Music	119,878,359	0.12	0.66	0.00	0.00	0.00	0.07	0.54	836.33
Gaming	119,878,359	0.12	1.13	0.00	0.00	0.00	0.00	0.29	789.63
Admin	119,878,359	0.05	0.41	0.00	0.00	0.00	0.01	0.18	246.95
Backup	119,878,359	0.03	0.58	0.00	0.00	0.00	0.00	0.05	694.27
CDN	119,878,359	0.11	0.77	0.00	0.00	0.00	0.01	0.38	542.75
Other	119,878,359	0.03	0.45	0.00	0.00	0.00	0.00	0.07	593.60
Sharing	119,878,359	0.01	0.32	0.00	0.00	0.00	0.00	0.00	408.40
Browsing	119,878,359	1.19	3.49	0.00	0.12	0.43	1.16	4.39	1,191.10
Streaming	119,878,359	0.32	1.40	0.00	0.00	0.01	0.14	1.46	841.76
Video	119,878,359	1.93	4.29	0.00	0.00	0.10	1.86	9.91	582.08

Note: This table reports distributional statistics of subscriber-day observations in our panel broken out by online activity category.

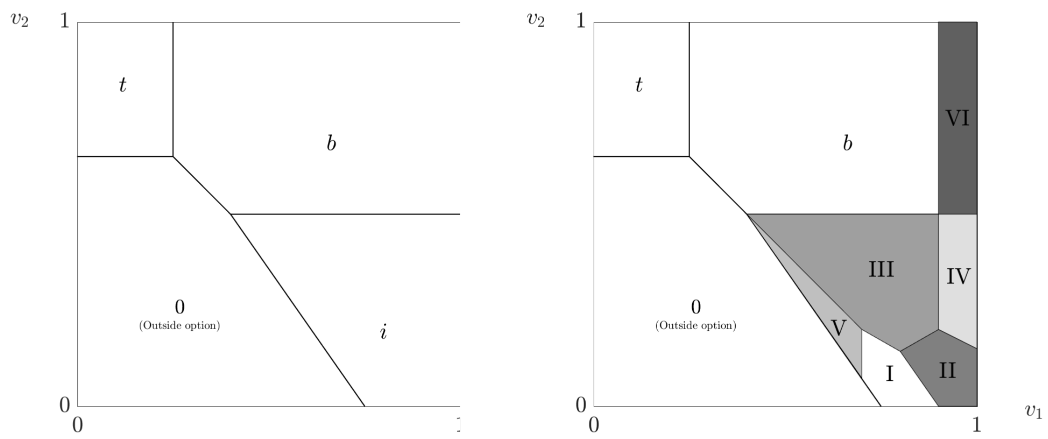
6.2 Additional discussion of theoretical model

We provide a more detailed description of how consumers' choices would be affected when the ISP introduces usage tiers. In practice, the tiers may vary in terms of usage allowances, overage prices, or connectivity speeds. We focus on a case in which the ISP, facing $\delta > 0$, shifts from having no tiers and no usage allowances to having both. This is similar to the situation in our data, and it also resembles the implementation of the tiering and UBP strategy that has been implemented by numerous North American ISPs.

In Figure 8 we demonstrate the effect of the ISP introducing a "low usage" tier which is subject to the usage allowance κ while a "high usage" tier has no usage limit. The same tiers are available to both internet-only and bundle subscribers (i_L and b_L for low-usage tiers, and i_H and b_H for high usage). We impose a set of prices that facilitate reading the different regions of Figure 8; the optimal prices and cap value would change the sizes and perhaps shapes of some regions.

Panel (a) of Figure 8 provides an initial distribution of consumers across subscription options, before any tiers or caps are offered. As in Figure 3 Panel (a), with $\delta > 0$ a significant share of consumers select the i subscription and satisfy their video entertainment tastes with OTTV. The introduction of usage tiers splits i and b subscribers into a new collection of actions, illustrated in Figure 8 Panel (b).

Figure 8: *Effect of Tiers and Allowances*



(a) Substitution (b) Substitution

Notes: This figure shows the effect of the introduction of a tier with a usage allowance on subscription choices. Throughout, δ is fixed at 0.7. Market shares are first plotted for prices $(p_i, p_t, p_b) = (0.75, 0.65, 0.9)$. Next, a usage allowance is placed on the original internet tier, and a new premium internet tier is introduced with no allowance. The new prices are $(p_{i,L}, p_{i,H}, p_t, p_{b,L}, p_{b,H}) = (0.75, 0.85, 0.65, 0.9, 1.0)$. Each shaded region depicts a set of consumer types that makes a particular subscription change. The usage allowances κ is equal to 0.8.

Former subscribers to the initial unlimited internet service (i) may update their subscription and usage choices in several ways. Some consumers, in Figure 8 Panel (b)'s area I, will accept the usage cap κ and remain internet-only. Consumers with a stronger taste for internet usage, whether for video- or non-video entertainment, may "upgrade" their internet subscription to i_H; these consumers are in Panel (b)'s area II. From the ISP's perspective, the tier upgrade is a way to have area II's consumers pay a greater price for internet service is equal to what the consumers received previously. Consumers with relatively strong values of v_2 switch from i into the bundle (areas

III and IV). Of these consumers, those with high values of v_1 pay for a tier upgrade in addition to TV service (area IV). When consumers switch to the bundle, they receive video entertainment through TV, so their OTTV usage falls to zero. Finally among initial i subscribers, some will cancel their subscriptions completely (area V) because their relatively strong taste for video entertainment and weak taste for non-video internet means that capped internet, at the present price, is worth less than the outside option. In addition to these margins for former i subscribers, some bundle subscribers with strong internet tastes (in area VI) will opt for b_H so that they can consume internet without a usage limit.

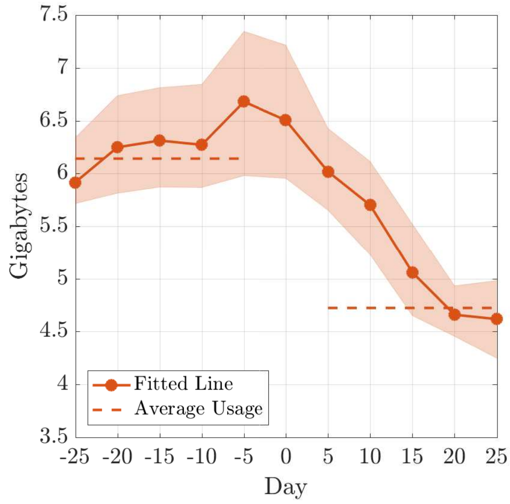
6.3 Add Video Usage Changes

The ISP's UBP policy has two types of benefit for the firm. First, it may induce switches in households' subscriptions which increase revenue; this is the impact we studied above. Second, it may lead consumers to reduce their internet usage, which can reduce pressure on the ISP to make costly investments in network capacity. We now consider whether the ISP was able to induce reductions in internet usage following the introduction of UBP.

We begin by examining the case of initially internet-only households that added a conventional TV subscription in the treated market. In Figure 9 we track the internet usage changes for households who added video to their subscriptions. Internet usage falls significantly after this subscription change. This reduction is consistent with the usage change described in Section 2's illustrative model. The reduction's magnitude (25%) is about equal in magnitude but opposite in sign to the change in internet usage that occurs after a household cuts the cord. Households induced by UBP to add video, therefore, appear to be steered away from heavy internet usage.

In addition to the revenue and cost implications for the ISP, there are also third-party services that may be impacted by steering. To examine this, in Table 7 we decompose by application the decrease in usage in Figure 9. Average usage of some types of applications like Music, Gaming, and Sharing increase slightly during our sample, while Streaming and Browsing remain at similar levels. The large and substantial usage decrease that we observe in Figure 9 is almost entirely due to a reduction in OTTV usage. The largest absolute reduction in usage is Netflix, while the largest percentage reduction is SlingTV. This mirrors the application-level usage changes by cord-cutting households that we describe in Section 3. The closest substitutes for pay-TV, linear-OTTV services, are most heavily impacted by steering, while other on-demand services are impacted to a lesser degree.

Figure 9: *Usage Before and After Addition of TV Service*



Notes: This figure presents statistics summarizing average daily usage (GBs) of customers on the days before and after adding TV services. The dots are average daily usage, the hashed line is average usage across days before and after, and the solid line is a global local-linear regression fit of the data.

6.4 Calculation of Price Impact of UBP

Let s represent a collection of ISP and OTTV subscriptions held by a household. To calculate the predicted price change to household h, $p_h(s)$, we use similar households in the treatment and control markets to estimate treatment-period internet usage, u', in the absence of UBP. Similar households are defined in terms of their ISP and OTTV subscriptions and their pre-policy usage, u.

Households in the treatment and control markets cannot predict perfectly how their internet usage will evolve between the pre-policy and treatment periods (in the absence of UBP), but they know the distribution of future usage. In particular, for each household h we calculate $F_h(u'|s)$, a probability distribution of internet usage for treated household h if it takes subscription s, defined as:

$$F_h(u'|s) = \sum_{j \in N_C(s)} \mathbb{1}[u'_j < u'] K\Big(\frac{u_i - u_j}{l}\Big). \tag{1}$$

In $F_h(u'|s)$, $N_C(s, \tau_h)$ is the set of control-market households with a particular s and sufficiently similar u values, as captured by the kernel function K which has bandwidth parameter l. An individual treated household's exposure to overage charges is determined by its pre-policy tier subscription, so we write $\mathcal{O}_h(u'|s)$ as h's charge in dollars from usage u' during the treatment period. Given F_h and $\mathcal{O}_h$, we calculate an individual household's expected price exposure as:

$$p_h(s) = \int \mathcal{O}_h(u'|s) dF_h(u'|s). \tag{2}$$

Table 7: Change in Usage After TV Add During UBP Implementation

Traffic Type	Average Usage (GBs)	
	Pre-Add	*Post-Add*
Browsing	1.67	1.43
Gaming	0.20	0.15
Music	0.18	0.16
OTTV	2.911	2.018
HBO Go	0.03	0.02
Hulu	0.17	0.07
Netflix	2.52	1.40
Sling TV	0.05	0.02
YouTube	1.00	0.74
Other Video	0.56	0.49
Other	0.26	0.21

Notes: This table reports average usage by traffic type for subscribers that add TV after UBP is implemented. Each average is taken across subscriber days for one month before and one month after adding pay TV.

6.5 Multinomial Logit Models

Table 8: Responses of Unbundled Subscribers to UBP

	(1)			(2)		
	Add	Upgrade	Both	Add	Upgrade	Both
Heavy User	0.20***	0.47***	0.35***	-0.42***	0.43***	0.33
	(0.043)	(0.038)	(0.104)	(0.110)	(0.074)	(0.201)
Treated Market	0.32***	0.00	0.04	0.32***	0.00	0.04
	(0.077)	(0.086)	(0.223)	(0.077)	(0.086)	(0.223)
Heavy × Treat	-0.40***	1.58***	0.76**	-0.58	1.42***	-0.13
	(0.157)	(0.106)	(0.311)	(0.473)	(0.178)	(0.775)
Heavy × Linear				0.18**	-0.02	0.22
				(0.078)	(0.071)	(0.188)
Heavy × Treat × Linear				0.50*	0.50***	0.78*
				(0.281)	(0.134)	(0.449)
Heavy × Netflix				0.66***	0.06	-0.03
				(0.114)	(0.078)	(0.214)
Heavy × Treat × Netflix				-0.03	-0.00	0.64
				(0.490)	(0.170)	(0.778)
Constant	-3.64***	-3.59***	-5.54***	-3.64***	-3.59***	-5.54***
	(0.025)	(0.024)	(0.063)	(0.025)	(0.024)	(0.063)
Observations	104790			104790		

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Responses of Bundled Subscribers to UBP

	(1)			(2)		
	Cut	Upgrade	Both	Cut	Upgrade	Both
Heavy User	0.50***	0.43***	0.99***	0.36***	0.41***	0.76***
	(0.035)	(0.028)	(0.090)	(0.085)	(0.065)	(0.215)
Treated Market	-0.10*	0.39***	0.44***	-0.10*	0.39***	0.44***
	(0.050)	(0.032)	(0.123)	(0.050)	(0.032)	(0.123)
Heavy × Treat	-0.08	1.07***	1.07***	-0.26	1.00***	0.38
	(0.133)	(0.061)	(0.189)	(0.370)	(0.142)	(0.558)
Heavy × Netflix				0.16*	0.02	0.27
				(0.090)	(0.069)	(0.224)
Heavy × Treat × Netflix				0.19	0.08	0.75
				(0.389)	(0.149)	(0.565)
Constant	-3.83***	-3.32***	-6.09***	-3.83***	-3.32***	-6.09***
	(0.017)	(0.013)	(0.051)	(0.017)	(0.013)	(0.051)
Observations	240370			240370		

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$