"Usage Based Pricing and Demand for Residential Broadband"

- Estimate model of willing ness to pay for broadband
- Use estimates to show that usage-based pricing improves overall welfare.

TABLE I

COMPOSITION AND USAGE GROWTH, 2012 VERSUS 2015[a]

Source	% of Usage		% Usage Growth
	2012	2015	2012 to 2015
Video	34.1	61.1	260.1
Web Browsing	31.9	21.5	36.2
File Sharing	8.3	0.2	−95.2
Gaming	1.3	3.1	357.1
Music	0.4	3.4	1,650.0
Backup	0.2	0.5	400.0
Other	23.7	10.3	−12.4
Total	100.0	100.0	101.5

[a]This table presents the percent of usage from different uses in 2012 and 2015, as well as the percent growth in GBs between 2012 and 2015 from each source and overall. The data are for June 2012 and June 2015 and come from a North American ISP, different from our main provider. In these data, we do not observe usage-based pricing, but we do see more information about the content.

TABLE II

DESCRIPTIVE STATISTICS OF SUBSCRIBER PLAN CHOICES AND USAGE, MAY–JUNE 2012[a]

	Unlimited Plans	Usage-Based Plans
Number of Subscribers	12,316	42,485
Plan Characteristics		
Mean Access Fee ($)	44.33	74.20
Mean Download Speed (Mb/s)	6.40	14.68
Mean Allowance (GB)	∞	92.84
Mean Overage Price ($/GB)	–	3.28
Usage		
Mean (GB)	50.39	43.39
Median (GB)	25.60	23.63
Median Price per GB ($)	1.68	3.02
Overages		
Mean Share of Allowance Used (%)	–	49.02
Subscribers Over Allowance (%)	–	9.45
Median Overage (GB)	–	17.03
Median Overage Charges ($)	–	51.19

[a]These statistics reflect characteristics of plans chosen and usage by subscribers to a single ISP, in four markets during May–June 2012. Usage is based upon Internet Protocol Detail Record (IPDR) data, captured in 15-minute intervals and aggregated to the monthly level. Means and medians are at the subscriber level.

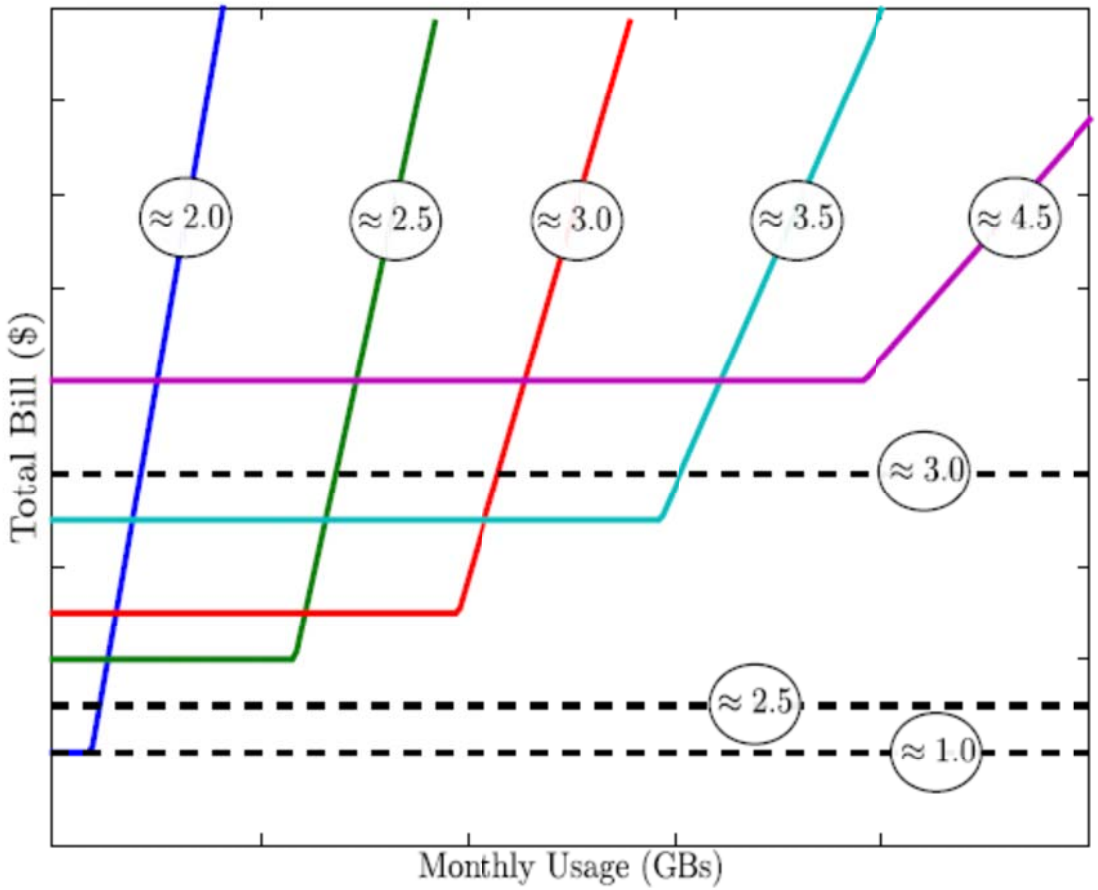


FIGURE 2.—Plan features and billing. *Note*: This figure illustrates the relationship between monthly usage and cost for the usage-based (solid lines) and grandfathered unlimited plans (dashed lines). The approximate relative speed for each plan, normalized by the slowest plan, is indicated by the circle intersecting each line.

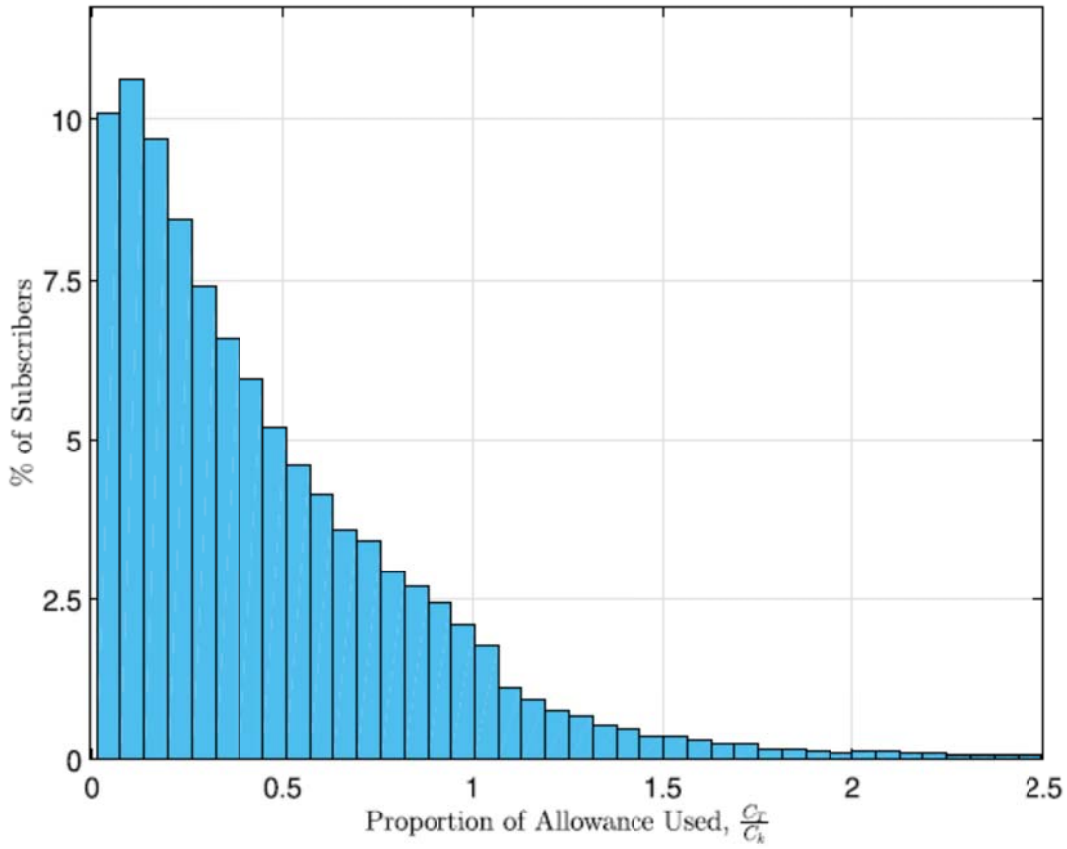


FIGURE 1.—Proportion of allowance used. *Note*: This figure presents a histogram where each observation represents a consumer's monthly usage relative to their allowance, both in GBs.

Data

- Year of broadband usage by consumer (modem) level
- Know what plan they have
- Idea is to use dynamics of where someone is in the monthly cycle.
- Look at descriptive regression)subscriber j on day t on plan k

$$\ln(c_{jkt}) = \sum_{m=1}^{M=4} \sum_{n=1}^{N=5} \alpha_{nm} 1\left[pct_n \leq \frac{C_{jk(t-1)}}{\bar{C}_k} < pct_{n+1}\right] 1\left[day_m \leq t < day_m\right.$$
$$+ x_t\psi + \mu_j + \varepsilon_{jkt}$$

- $\frac{C_{jk(t-1)}}{\bar{C}_k}$ is proportation of allowance used up.

TABLE III

FORWARD-LOOKING BEHAVIOR, WITHIN-MONTH REGRESSION[a]

	$\mathbb{1}[10 \le t < 15]$	$\mathbb{1}[15 \le t < 20]$	$\mathbb{1}[20 \le t < 25]$	$\mathbb{1}[25 \le t < 31]$
$\mathbb{1}[0 \le \frac{C_{jk(t-1)}}{\overline{C}_k} < 0.40]$	−0.04**	−0.04**	0.03**	0.08**
	(0.01)	(0.01)	(0.01)	(0.01)
$\mathbb{1}[0.40 \le \frac{C_{jk(t-1)}}{\overline{C}_k} < 0.60]$	−0.02	−0.12**	−0.12**	−0.04**
	(0.02)	(0.01)	(0.01)	(0.01)
$\mathbb{1}[0.60 \le \frac{C_{jk(t-1)}}{\overline{C}_k} < 0.80]$	−0.07**	−0.12**	−0.20**	−0.16**
	(0.03)	(0.02)	(0.02)	(0.01)
$\mathbb{1}[0.80 \le \frac{C_{jk(t-1)}}{\overline{C}_k} < 1.00]$	−0.19**	−0.26**	−0.39**	−0.42**
	(0.05)	(0.03)	(0.02)	(0.02)
$\mathbb{1}[1.00 \le \frac{C_{jk(t-1)}}{\overline{C}_k}]$	−0.12**	−0.35**	−0.41**	−0.47**
	(0.05)	(0.03)	(0.02)	(0.02)
Adjusted R^2	0.46			

[a]This table presents OLS estimates of Equation (1) using 1,644,030 subscriber-day observations. The dependent variable is natural logarithm of daily usage. Each cell in the table gives the coefficient on the interaction between the indicators in the respective row and column. Controls include a constant, time trend, indicators for the day of the week, and subscriber fixed effects. Asterisks denote statistical significance: **1% level, *5% level.

FIGURE 3.—Across-month dynamics. *Note*: This figure presents how the percentage change in usage from the last day of a billing cycle to the first day of the next varies with the proportion of the allowance consumed by a subscriber at the end of the billing cycle.

Model

- Plan k
  - speed s_k
  - Usage allowance $\bar{C}_k$
  - F_k fixed fee
  - p_k overage price

- Type h has utility

$$u_h(c_t, y_t, v_t, : k) = v_t \left(\frac{c_t^{1-\beta_h}}{1-\beta_h} \right) - c_t \left(\kappa_{1h} + \frac{\kappa_{2h}}{\ln(s_k)} \right) + y_t$$

- v_t distributed log normal μ_h and σ_h.

- Subscriber of type h summarized by $(\beta_h, \kappa_{1h}, \kappa_{2h}, \mu_h, \sigma_h)$.

- Problem (given k)

$$\max_{(c_1,\ldots,c_T)} \sum_{t=1}^{T} E[u_h(c_t, y_t, v_t; k)$$

$$\text{such that } F_k + p_k \max\left\{C_T - \bar{C}_k, 0\right\} + Y_T \leq I$$

$$C_T = \sum_{j=t}^{T} c_t$$

$$Y_T = \sum_{t=1}^{T} y_t.$$

- Unused allowance $\bar{C}_{kt} = Max\left\{\bar{C}_k - C_{t-1}, 0\right\}$

- Overage $O_{tk}(c_t) = Max\left\{c_t - \bar{C}_{kt}, 0\right\}$

- Terminal period T, no uncertainty, below allowance

$$\frac{\partial u_h(c_t, y_t, v_t, : k)}{\partial c_t} = 0$$

Above

$$\frac{\partial u_h(c_t, y_t, v_t, : k)}{\partial c_t} = p_k$$

if $C_{t-1} < \bar{C}_k$, there is a range of v_t where at cap. Let $c^*_{hkT}(C_{T-1}v_T)$ be the solution.

$$V_{hkT}(C_{T-1}, v_T) = v_T(\frac{\left(c^*_{hkT}\right)^{1-\beta_h}}{1-\beta_h}) - c^*_{hkT}\left(\kappa_{1h} + \frac{\kappa_{2h}}{\ln(s_k)}\right) + y_t - p_k O_{tk}(c^*_{hkT})$$

- More generally

$$V_{ht}(C_{t-1}v_t) = \max_{c_t} \left\{ v_T(\frac{c_t^{1-\beta_h}}{1-\beta_h}) - c_t \left(\kappa_{1h} + \frac{\kappa_{2h}}{\ln(s_k)} \right) + y_t - p_k O_{tk}(c^*_{hkT}) + \right.$$

- shadow price of consumption

$$\tilde{p}_k(c_t, C_{t-1}) = \begin{cases} p_k & \text{if } O_{tk}(c_t) > 0 \\ \frac{dE\left[V_{h(t+1)}(C_{t-1}+c_t),v_{t+1}\right]}{dc_t} & \text{if } O_{tk}(c_t) = 0 \end{cases}$$

$$c^*_{hkt} = \left(\frac{v_t}{\kappa_{1h} + \frac{\kappa_{2h}}{\ln(s_k)} + p_k} \right)^{\frac{1}{\beta_h}}$$

- Optimal plan choice

$$k^*_h = \arg\max_k \{E[V_{hk1}(0) - F_k\}$$

Or put in some randomness here, maximize

$$\rho E\left[V_{hk0}(0) + \varepsilon_{hk} - F_k\right]$$

Estimation (Two-Step approach (Ackerberg (2009), Bajari, Fox, Ryan (2007)

- Step 1: Solving the model
- Calculate model for 16,807 types (each type h $(\beta_h, \kappa_{1h}, \kappa_{2h}, \mu_h, \sigma_h)$
- Grid C_{t-1} into 2000, then for 30 days have 60,000 states.
  - For each h, calculate transition on grid of C_{t-1}.
- Step 2: Estimation. θ is weight on types.

$$\hat{\theta} = \arg\min_{\theta} m_k(\theta)' \hat{V}' m_k(\theta)$$

subject to

$$\sum_{h=1}^{H_k} \theta_h = 1,\ \theta_h \geq 0$$

- plan specific vector $m_k(\theta)$ is given by

$$m_k(\theta) = \hat{m}_k^{dat} - m_k^{\text{mod}}\theta$$

- First moment to focus on: mean usage at each state

$$\sum_{h=1}^{H} E[c_{hkt}^*(C_{t-1})]\gamma_{hkt}(C_{t-1})\theta_h,$$

where

  - $E[c_{hkt}^*(C_{t-1})]$ is means usage of type h in time t under plan k and past usage C_{t-1}

- $\gamma_{hkt}(C_{t-1})$ is probablility type reaches state. (Average taken across all types,

- In data first estimate nonparametrically,

$$E[c^*_{hkt}(C_{t-1})]$$

Then estimate $\gamma_{hkt}(C_{t-1})$ from the data. (estimat the probability of observing a subscriber at state (C_{t-1}, t)

- Second moment to focus on: mass of subscribers at particular state

$$\sum_{h=1}^{H} \gamma_{hkt}(C_{t-1})\theta_h$$

- Discuss identification

– even the ones that have constant marginal price

– then the ones where marginal price varies

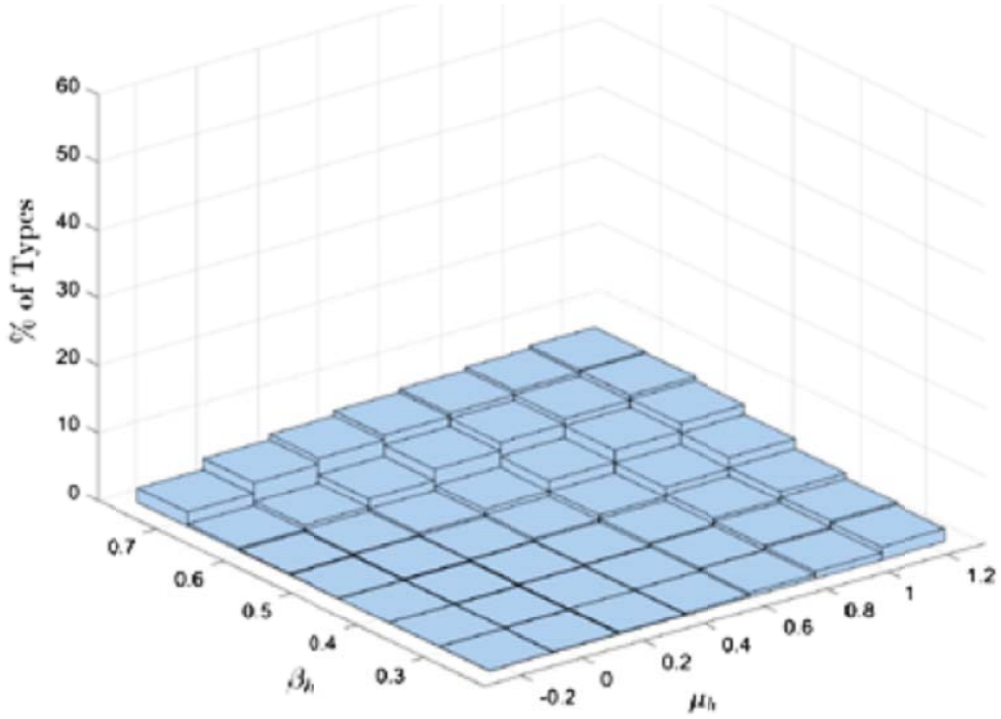
Results

- Weight $>$0.01% ($\theta_h > 0.0001$) for 53 types,
  - most common accounts for 28% (top 5 65%, top 10 78%, top 20 90%0
  - most common predicted to us 29GB month, willingness to pay \$72 for plan with 14.68Mb/s
- Figure 4
- Figure 5: Fit of of moment not used in estimation
- Out of sample fit. Have other data.

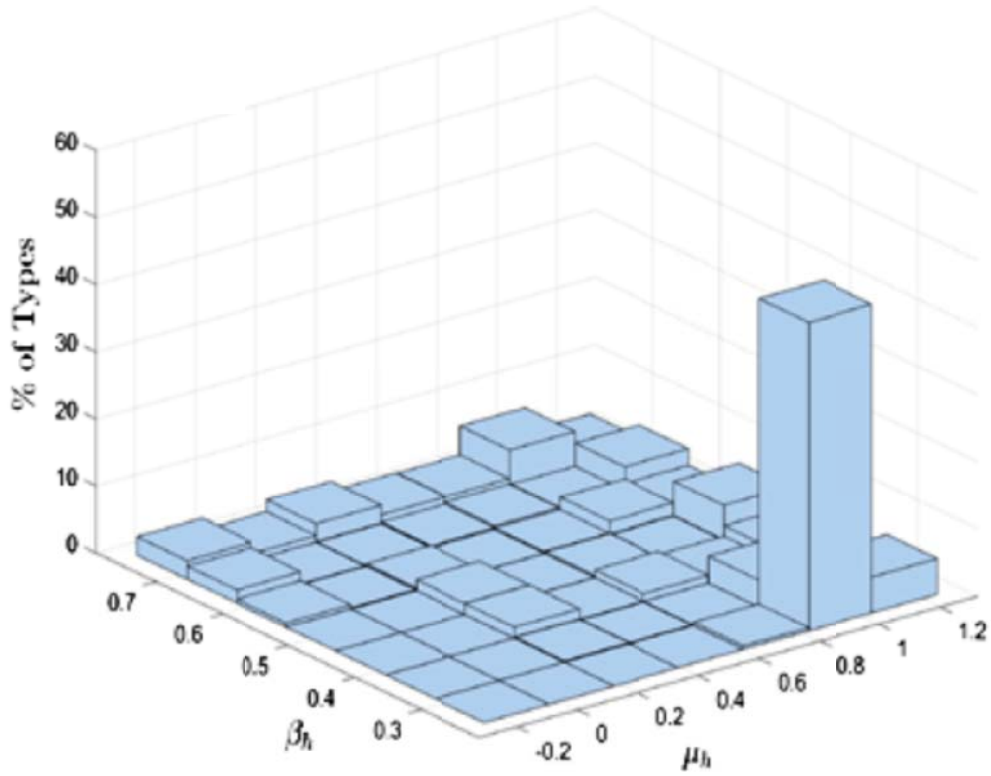
  - predict usage in June 2012 and 2015

  - match growth rate in the data almost exactly (change in plan characteristics, price and speed.) Cool (not sure why there is not table for this trophy.

- Look at tables for counterfactuals



(a) Only plan selection



(b) Plan selection and usage

FIGURE 4.—Sources of identification: plan selection and usage. *Note*: (a) presents the joint distribution of the utility curvature parameter, β_h, and the mean of shocks, μ_h, when only information on optimal plan selection is used and uniform weights within group are applied. (b) presents the distribution when information on optimal plan selection is used and the weights are chosen to match usage moments from the data.

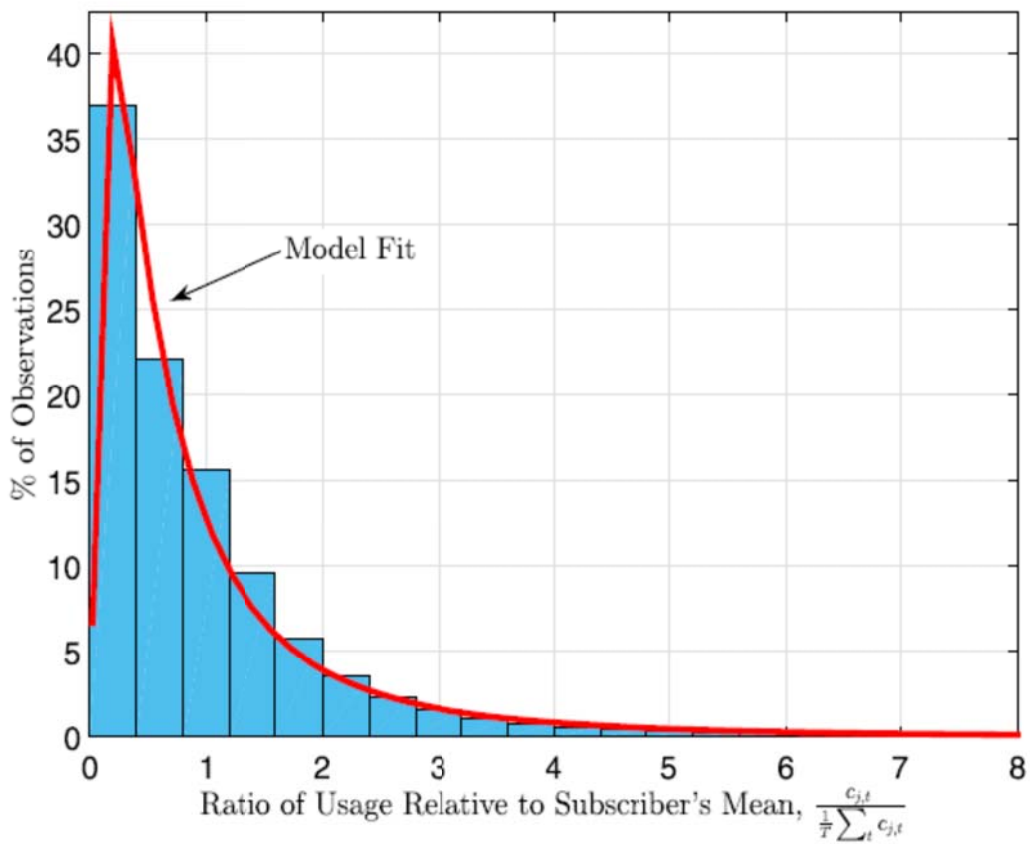
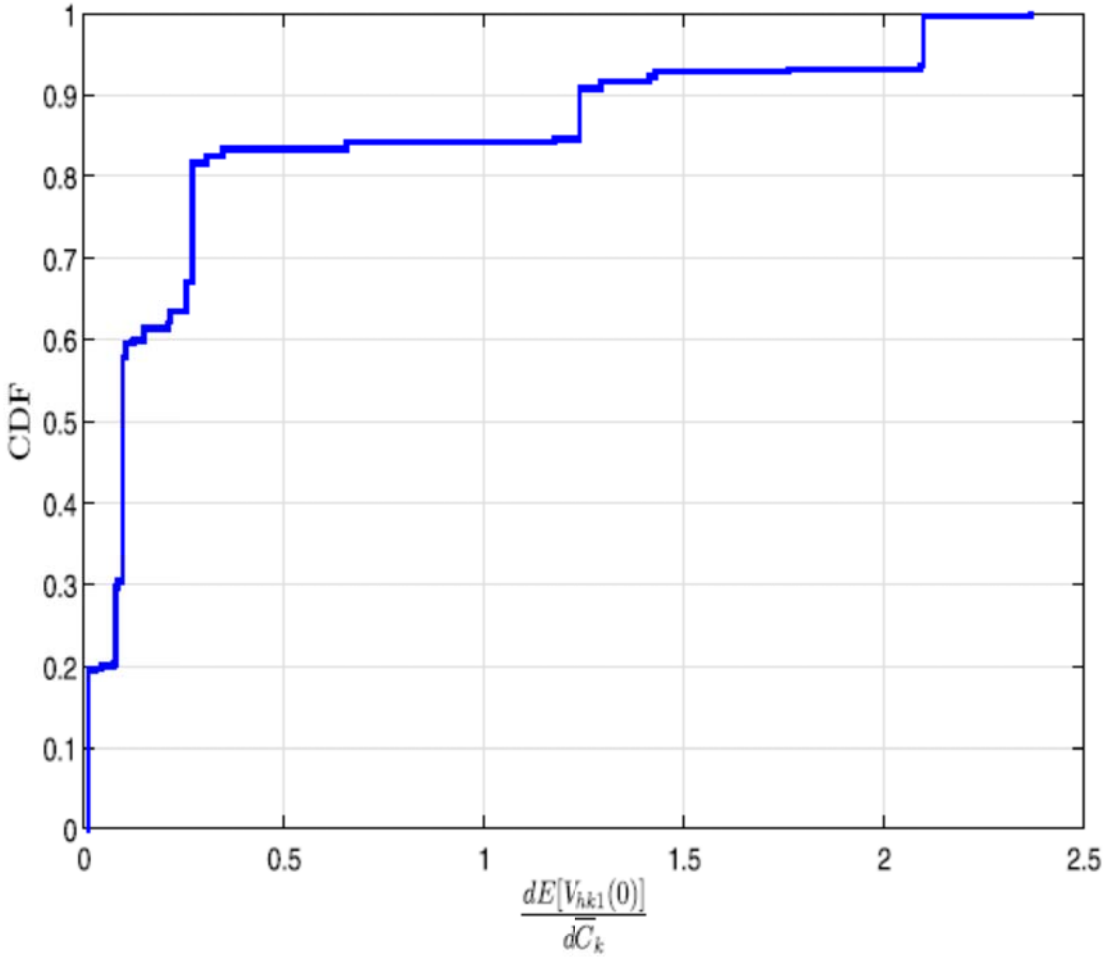
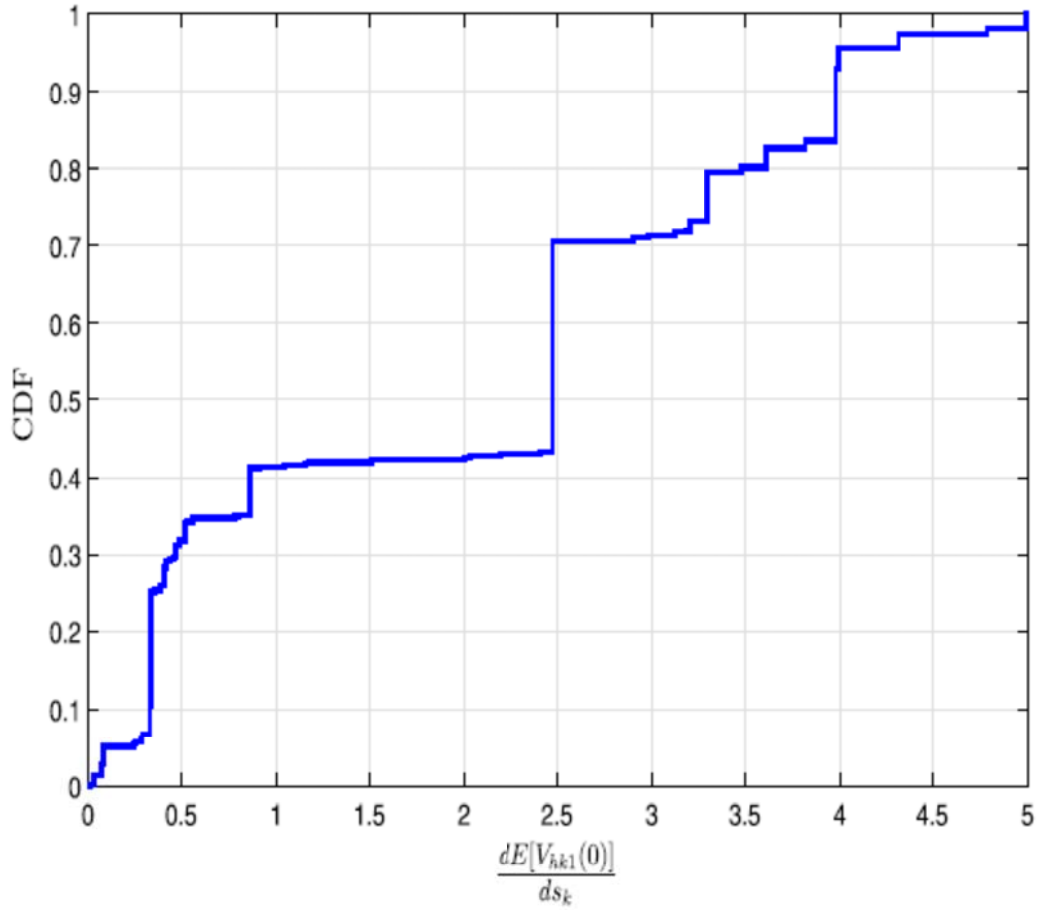


FIGURE 5.—Model fit: distribution of usage relative to a subscriber's mean. *Note*: This figure presents the ratio of daily usage, c_{jt}, to a subscriber's monthly average, $\frac{1}{T}\sum_t c_{jt}$, from the data and simulations from the model.



(a) Value of increasing usage allowance by 1 GB



(b) Value of increasing speed by 1 Mb/s

FIGURE 6.—Distributions of value of increasing usage allowance by 1 GB and speed by 1 Mb/s. *Note*: (a) and (b) show the distribution of willingness to pay to increase usage allowance by 1 GB and to increase speed by 1 Mb/s, respectively.

$$D(p) = \sum_{h=1}^{H} \widehat{\theta}_h \int_0^{\overline{v}_h} \left(\frac{v}{\kappa_{1h} + \dfrac{\kappa_{2h}}{\ln(s)} + p} \right)^{1/\beta_h} dG_h(v).$$

in Table IV we present expected demand for five different speeds: (1) 2 Mb/s, a relatively slow speed by most standards; (2) 14.68 Mb/s, the average speed

TABLE IV

EXPECTED DAILY USAGE UNDER A LINEAR TARIFF[a]

	Speed (Mb/s)				
Price ($)	2	14.68	50	100	1,024
0.00	0.97	2.20	2.97	3.42	4.62
	(0.005)	(0.010)	(0.015)	(0.018)	(0.034)
1.00	0.50	1.14	1.50	1.70	2.31
	(0.002)	(0.001)	(0.005)	(0.006)	(0.009)
2.00	0.29	0.66	0.86	0.96	1.24
	(0.001)	(0.002)	(0.003)	(0.003)	(0.004)
3.00	0.18	0.42	0.54	0.59	0.74
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
4.00	0.12	0.29	0.36	0.39	0.48
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
5.00	0.09	0.21	0.25	0.28	0.33
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)

[a]This table presents the expected daily usage averaged across all subscriber types when facing a linear tariff. Standard errors, in parentheses, are calculated using a block-resampling methodology as described in the text.

TABLE V

USAGE-BASED PRICING VERSUS UNLIMITED PLANS[a]

	(1)	(2)	(3)	(4)
Scenario Description				
UBP/Unlimited	UBP	Unlim	Unlim	Unlim
Plan Attributes	current	current	typical US	rev-max F_k
Usage and Surplus				
Usage (GBs)	48.2	60.2	62.0	65.4
	(0.203)	(0.261)	(0.264)	(0.322)
Speed (Mb/s)	14.2	10.3	10.8	12.6
	(0.021)	(0.010)	(0.018)	(0.069)
Consumer Surplus ($)	84.7	111.9	113.5	97.1
	(0.810)	(0.791)	(0.789)	(0.810)
Revenue ($)	69.4	42.1	44.8	64.3
	(0.132)	(0.044)	(0.068)	(0.209)

[a]This table presents estimates of usage, surplus, and revenue information for several scenarios. Standard errors, in parentheses, are calculated using a block-resampling methodology as described in the text.

TABLE VI

ADOPTION OF FTTP AND USAGE[a]

	(1)	(2)	(3)	(4)	(5)	(6)
Scenario Description						
Fee (F_k)	0	70	70	70	rev-max	rev-max
Competition			KC-cable	U-verse	KC-cable	U-verse
Usage and Surplus						
Usage (GBs)	138.8	136.6	134.5	134.4	133.1	132.0
	(0.855)	(0.857)	(0.856)	(0.871)	(0.901)	(0.897)
Speed (Mb/s)	1024.0	977.9	687.0	673.0	596.4	592.8
	(0.000)	(1.481)	(3.597)	(4.022)	(3.482)	(3.461)
Consumer Surplus ($)	279.4	212.9	213.2	215.5	194.3	175.0
	(1.025)	(1.014)	(0.968)	(0.981)	(0.922)	(0.889)
Revenue ($)	0.00	66.8	55.3	58.5	77.7	95.3
	(0.000)	(0.101)	(0.125)	(0.133)	(0.197)	(0.231)
FTTP Share (%)	100.0	95.5	64.7	67.1	57.2	57.2
	(0.000)	(0.145)	(0.359)	(0.397)	(0.348)	(0.351)

[a]This table presents estimates of average usage, speed consumer surplus, revenue, and adoption for pricing options of FTTP as well as other broadband offerings. The adoption rates are for the population we estimated, namely, the users of broadband subscribers. Standard errors, in parentheses, are calculated using a block-resampling methodology as described in the text.

TABLE VII

MUNICIPAL BROADBAND[a]

	(1)	(2)	(3)	(4)	(5)	(6)
Plan Description						
Fee ($)	50	75	50	75	50	75
Speed (Mb/s)	25	25	50	50	100	100
Usage and Surplus						
Usage (GBs)	75.4	72.9	88.9	87.9	102.2	101.1
	(0.344)	(0.339)	(0.432)	(0.429)	(0.532)	(0.530)
Speed (Mb/s)	24.6	21.0	49.2	46.2	98.4	92.5
	(0.029)	(0.047)	(0.058)	(0.098)	(0.110)	(0.195)
Consumer Surplus ($)	132.1	108.4	153.7	129.8	173.9	149.9
	(0.827)	(0.818)	(0.855)	(0.846)	(0.888)	(0.878)
Revenue ($)	49.2	63.0	49.2	69.3	49.2	69.3
	(0.058)	(0.141)	(0.058)	(0.147)	(0.055)	(0.146)
Muni-BB Share (%)	98.4	84.0	98.4	92.4	98.4	92.4
	(0.124)	(0.178)	(0.121)	(0.142)	(0.123)	(0.140)

[a]This table presents estimates of average usage, speed, consumer surplus, and revenue for pricing options of typical municipal broadband offerings. The adoption rates are for the population we estimated, namely, broadband subscribers. Standard errors, in parentheses, are calculated using a block-resampling methodology as described in the text.