Cellular service demand: biased beliefs, learning and bill shock

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Disclaimer

The views expressed herein are those of the authors and not necessarily those of the Bureau of Economic Analysis or the U.S. Department of Commerce.

Overview

- Estimate a model of tariff & usage choice, marginal-price uncertainty, biased beliefs, and learning using cellular phone billing data.
- Consumers are aware of their own uncertainty about marginal prices.
  - Incorporate optimal threshold rule for accepting/rejecting calls
- Identifying Biased Beliefs:
  - True distribution of tastes (from usage patterns)
  - Prior beliefs & learning rate (from plan choices and switches)
  - Biases measure systematic differences between the two, and lead to predictable mistakes
- Counterfactuals
  - How costly are consumer biases?
  - FCC's bill-shock regulation in 2013?

Data Overview

- Individual cellular billing data 8/2002 - 7/2004
  1366 students subscribing through a major US university.
- Pricing data for all cellular phone carriers 2002-2005 (EconOne)
- Popular plan prices, Spring 2003:

Plan	M_j	Q_j	p_j
Plan 0	\$14.99	0	\$0.11
Plan 1	\$34.99	380	\$0.45
Plan 2	\$44.99	653	\$0.40
Plan 3	\$54.99	875	\$0.40

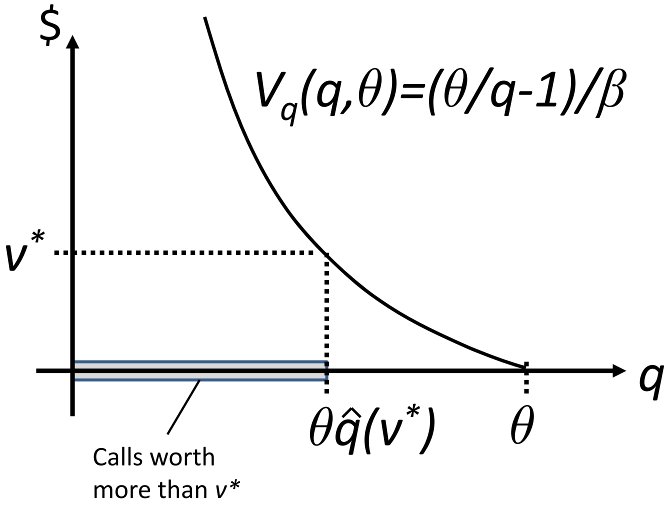
Illustrative Model: Timing and usage choice

1. Consumers choose a plan j and a calling threshold v^*_{itj} based on beliefs about distribution of θ_{it}.
2. During the course of the month θ_{it} calling opportunities arise. Consumers make all calls worth more than v^*_{itj}
3. Fraction $\hat{q}(v^*)$ of calls valued above v^*. At the end of the month, realized usage is $q_{it} = \theta_{it}\hat{q}(v^*_{it})$.

- In our model $\hat{q}(v^*_{it}) = \frac{1}{1+\beta v^*}$.

Inverse Demand Curve and Calling Threshold

- Value of minutes: $V(q,\theta) = (\theta log(q/\theta) - q)/\beta$



Projection Bias

- Taste shock θ_{it} is a latent shock censored at zero

$$\theta_{it} = \begin{cases} 0 & \tilde{\theta}_{it} < 0 \\ \tilde{\theta}_{it} & \tilde{\theta}_{it} \geq 0 \end{cases}.$$

- Latent taste shock $\tilde{\theta}_{it} = \mu_i + \varepsilon_{it}$ is normally distributed:

$$\text{Truth:} \quad \tilde{\theta}_{it} \sim N\left(\mu_i, \sigma_\varepsilon^2\right)$$

$$\text{Belief:} \quad \tilde{\theta}_{it} \sim N\left(\mu_i, \tilde{\sigma}_\varepsilon^2\right), \ \tilde{\sigma}_\varepsilon = \delta_\varepsilon \sigma_\varepsilon$$

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- $\delta_\varepsilon < 1 \rightarrow$ consumers underestimate the volatility of their tastes month to month (projection bias).

Overconfidence

- Consumers are uncertain about their own types: μ_i
- Each consumer has initial point estimate of her type $\tilde{\mu}_{i1} \sim N(\tilde{\mu}_0, \tilde{\sigma}_\mu^2)$ (which she updates over time by Bayes rule.)
- Population variance of true types among customers with the same point estimate is

$$\sigma_\mu^2 = Var(\mu_i | \tilde{\mu}_{i1})$$

- Prior beliefs:

$$\mu_i | \Im_{i,1} \sim N(\tilde{\mu}_{i,1}, \tilde{\sigma}_1^2),$$

$$\tilde{\sigma}_1 = \delta_\mu \sigma_\mu$$

- $\delta_\mu < 1 \rightarrow$ Overconfidence, underestimate uncertainty about own type.

Selected Parameter Estimates

- Price Coefficient β: 3.4 (0.05)
  $\rightarrow$ Increase from 0 to 11 cent/min reduces usage $\approx$ 27%

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σ_ε	169 (0.54)	$\tilde{\sigma}_\varepsilon$	91 (1.1)	δ_ε	0.54 (0.01)	Projection Bias (too risky plans)

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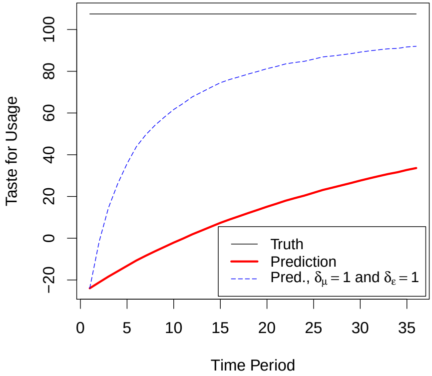
μ_0	107 (1.8)	$\tilde{\mu}_0$	-25 (6.7)	b_1	-132 (7.0)	Neg. Mean Bias (too small plans)

* Risk-aversion $\rightarrow$ estimates of overconfidence and projection bias are a lower bound

Biases Lead to Slower Learning



- Without overconfidence or projection bias, mean bias would be reduced 70% by learning in the first year. Actual reduction is only 20%.

Impact of De-Biasing on University Plan Shares

Offered Plan	0	1	2	3	Other
Estimates	42.8	28.6	13.7	5.5	9.4
$\delta_\mu = 1$ and $\delta_\epsilon = 1$	39.8	25.7	17.8	7.1	9.6
No Biases	46.6	17.5	18.4	8.5	9.0

Impact of De-Biasing on Welfare (University Plans)

	Estimates	$\delta_\mu = 1$ and $\delta_\epsilon = 1$
Avg. Bill	41.37	37.96
Ovg. Prob.	0.2	0.1
Δ Monthly Fee		1.53
Δ Overage Fee		-4.32
Δ Bill		-3.41
Δ q | Overage		-34
Δ q		-14.5
Δ Profit (Annual)		-40.89
Δ Cons. Welf. (Annual)		29.9
Δ Tot. Welf. (Annual)		-10.99

Impact of De-Biasing on Welfare (University Plans)

	Estimates	$\delta_\mu = 1$ and $\delta_\epsilon = 1$	No Biases
Avg. Bill	41.37	37.96	36.3
Ovg. Prob.	0.2	0.1	0.05
Δ Monthly Fee		1.53	0.51
Δ Overage Fee		-4.32	-5.76
Δ Bill		-3.41	-5.07
Δ q | Overage		-34	-12
Δ q		-14.5	-12.2
Δ Profit (Annual)		-40.89	-60.79
Δ Cons. Welf. (Annual)		29.9	51.3
Δ Tot. Welf. (Annual)		-10.99	-9.49

Impact of De-Biasing on Welfare (Public Plans)

	Estimates	$\delta_\mu = 1$ and $\delta_\epsilon = 1$
Avg. Bill	49.24	41.77
Ovg. Prob.	0.23	0.12
Δ Monthly Fee		1.21
Δ Overage Fee		-8.68
Δ Bill		-7.47
Δ q | Overage		-41
Δ q		-28.1
Δ Profit (Annual)		-89.66
Δ Cons. Welf. (Annual)		64.83
Δ Tot. Welf. (Annual)		-24.84

Impact of De-Biasing on Welfare (Public Plans)

	Estimates	$\delta_\mu = 1$ and $\delta_\epsilon = 1$	No Biases
Avg. Bill	49.24	41.77	40.73
Ovg. Prob.	0.23	0.12	0.06
Δ Monthly Fee		1.21	3.18
Δ Overage Fee		-8.68	-11.69
Δ Bill		-7.47	-8.51
Δ q | Overage		-41	-10
Δ q		-28.1	-20.4
Δ Profit (Annual)		-89.66	-102.12
Δ Cons. Welf. (Annual)		64.83	86.64
Δ Tot. Welf. (Annual)		-24.84	-15.48

Equilibrium Price Response to Bill-Shock Regulation

		Est (1)	Est, Bill Shock (fixed prices) (2)	Est, Bill Shock (3)
Plan 1	M	28.46	28.46	28.36
	Q	0	0	0
	p	50	50	50
	Share	63	63	72
Plan 2	M	61.28	61.28	73.99
	Q	295	295	374
	p	50	50	50
	Share	37	37	28
Profit		915	882	919
Cons Welfare		5497	5515	5465
Total Welfare		6413	6396	6384

Equilibrium Price Response to Bill-Shock Regulation

		$\delta_\mu = 1$ and $\delta_\varepsilon = 1$ (4)	No Biases (5)
Plan 1	M	29.26	78.07
	Q	0	∞
	p	50	N/A
	Share	64	49
Plan 2	M	78.95	78.07
	Q	∞	∞
	p	N/A	N/A
	Share	36	51
Profit		925	937
Cons Welfare		5501	5695
Total Welfare		6425	6632

Conclusion

- We estimate a model of tariff & usage choice, marginal-price uncertainty, biased beliefs, and learning using cellular phone billing data

- Estimates
  - Overconfidence: underestimate uncertainty about mean usage by 82%
  - Projection Bias: underestimate monthly volatility in usage by 46%

- Biases significantly decrease consumer welfare
  - Overconfidence and projection bias hurt consumers $30/year (6% avg. bill)
  - All biases hurt consumers $51/year (10% avg. bill)

Conclusion

- We estimate a model of tariff & usage choice, marginal-price uncertainty, biased beliefs, and learning using cellular phone billing data

- Estimates
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  - All biases hurt consumers \$51/year (10% avg. bill)

- Bill shock regulation...
  - helps consumers if prices are fixed
  - may hurt consumers if prices vary

Predictable Mistakes and Savings Opportunities

- Customers beliefs are biased, so make predictable mistakes.
- Evidence from "arbitrage opportunities"
    - University acts as a reseller, charging a fixed $5 fee per month
    - University could bill students for their chosen plan, but sign them up for an alternative plan, and pocket the difference in charges.

	First Opportunity	Second Opportunity
Dates	10/02-8/03	9/03 onwards
Enrollment Change	plan 1-3 $\rightarrow$ plan 0	plan 1 $\rightarrow$ plan 2
Affected Customers	251 (34%)	445 (55%)
Additional Revenue		
Total	$20,840 (47%)	$7,942 (28%)
Per Affected Bill	$8.76	$2.64
Per Affected Cust.	$83.03 (149%)	$17.85 (46%)

Debiasing Counterfactuals: (with University Plans)

Table: Dollar values in percentage terms

	Estimates	$\delta_\mu = 1$ and $\delta_\epsilon = 1$	No Biases
Avg. Bill			
Ovg. Prob.			
Δ Monthly Fee		0.04	0.01
Δ Overage Fee		-0.1	-0.14
Δ Bill		-0.08	-0.12
Δ q | Overage			
Δ q			
Δ Profit (Annual)		-0.08	-0.12
Δ Cons. Welf. (Annual)		0.06	0.1
Δ Tot. Welf. (Annual)		-0.02	-0.02

Debiasing Counterfactuals: Public Plan Shares

Offered Plan	0	1	2	3	Other
NA	0.0	23.2	11.7	4.9	60.2
NA	0.0	20.9	13.9	5.6	59.6
NA	0.0	15.5	16.6	8.9	59.0

Illustrative Model: Consumer Utility

- Each date t, consumer i chooses a plan j, and then a quantity q_{it}.
- Consumer utility is

$$u_{itj} = V(q_{it}, \theta_{it}) - \alpha P_j(q_{it}) + \eta_{itj}$$

$V(q_{it}, \theta_{it})$ is the value of consuming q_{it} units given taste shock θ_{it},

$$V(q_{it}, \theta_{it}) = \frac{1}{\gamma}\left(\theta_{it} ln(q_{it}/\theta_{it}) - q_{it}\right)$$

$P_j(q_{it})$ is the payment for usage q_{it} on plan j,

$$P_j(q_{it}) = M_j + p_j \max\{0, q_{it} - Q_j\}$$

and η_{itj} is an iid logit error.

Illustrative Model: Consumer Demand

- Let $q(p, \theta_{it})$ be consumer demand given constant marginal price p:

$$q(p, \theta_{it}) \equiv \arg\max_q V(q, \theta_{it}) - pq,$$

- Define $\beta = \alpha\gamma$. Then

$$\begin{aligned} q(p, \theta_{it}) &= \theta_{it}\hat{q}(p) \\ \hat{q}(p) &= 1/(1+\beta p) \end{aligned}$$

Interpretation:

- θ_{it} call opportunities arise in billing period
- $\hat{q}(p)$ is the fraction of calls worth more than p

Illustrative Model: Timing and usage choice

1. Consumers choose a plan j and a calling threshold v^*_{itj} based on beliefs about distribution of θ_{it}.

2. During the course of the month consumers do not track usage, but simply make all calls valued above v^*_{it}:[1]

$$v^*_{itj} = p_j \Pr\left(\theta_{it} \geq Q_j/\hat{q}(v^*_{itj})\right) \frac{E\left[\theta_{it} \mid \theta_{it} \geq Q_j/\hat{q}(v^*_{itj});\ \Im_{it}\right]}{E\left[\theta_{it} \mid \Im_{it}\right]}$$

3. At the end of the month, realized usage is $q_{it} = \theta_{it}\hat{q}(v^*_{it})$.

[1] Optimal strategy for an inattentive consumer who does not keep track of past usage.

Identification Overview

1. True tastes: σ_ε, and population distribution of μ_i.
   - usage patterns
2. Beliefs: $\tilde{\sigma}_\varepsilon$, $\tilde{\sigma}_1$, and population distribution of $\tilde{\mu}_{i1}$.
   - Initial plan choice shares and switching
3. Price coefficient β
   - 9pm usage increase

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