The Demand for Bandwidth

Evidence from the INDEX Project

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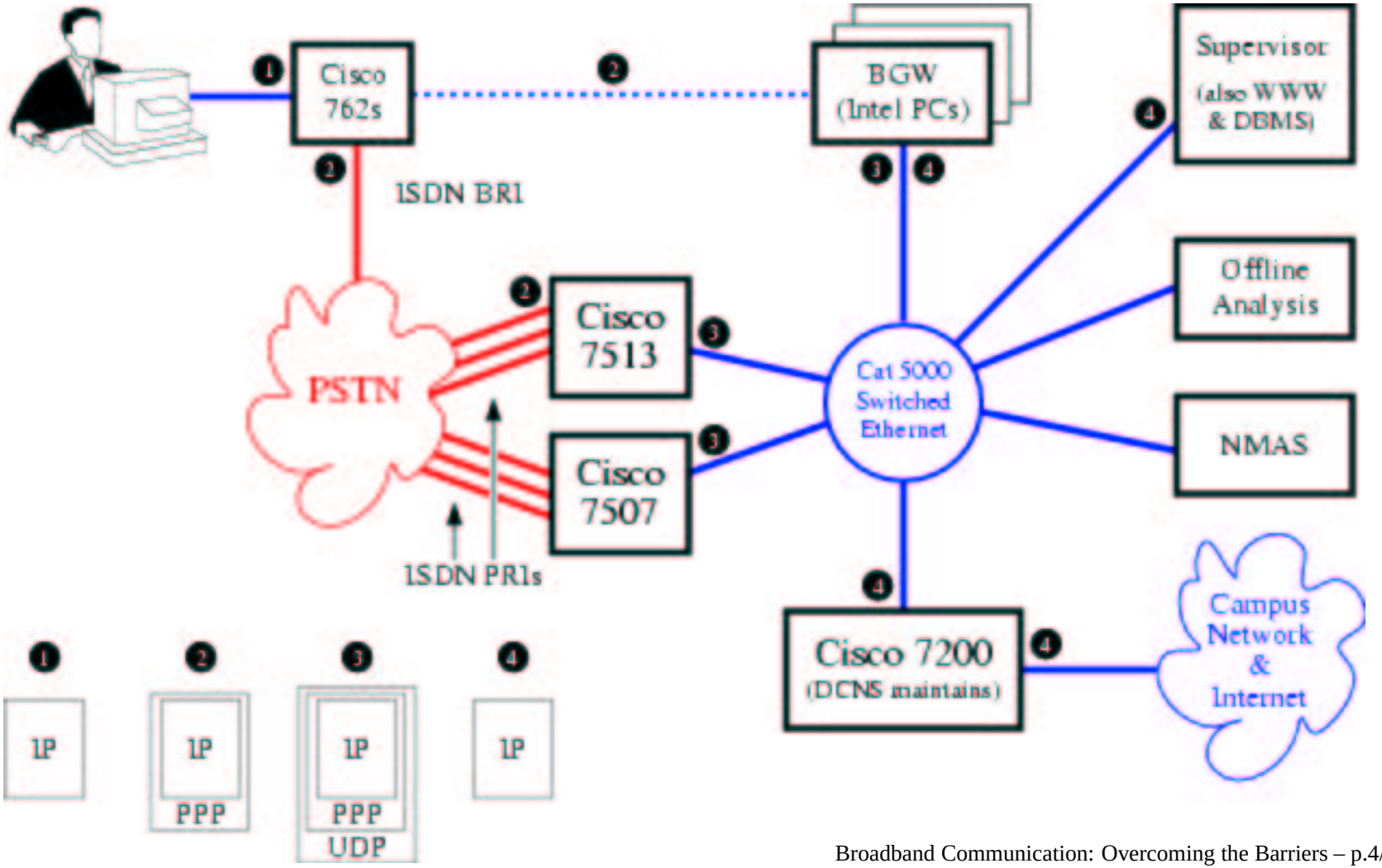
The INDEX project

- An experiment to estimate how much people were willing to pay for bandwidth.
- Ran from April 1998 to December 1999.
- Funded by NSF, Cisco, HP.
- Principal investigators:: Pravin Varaiya, Hal Varian. Graduate researchers: Richard Edell, Karyen Chu, Walter Beckert and others.

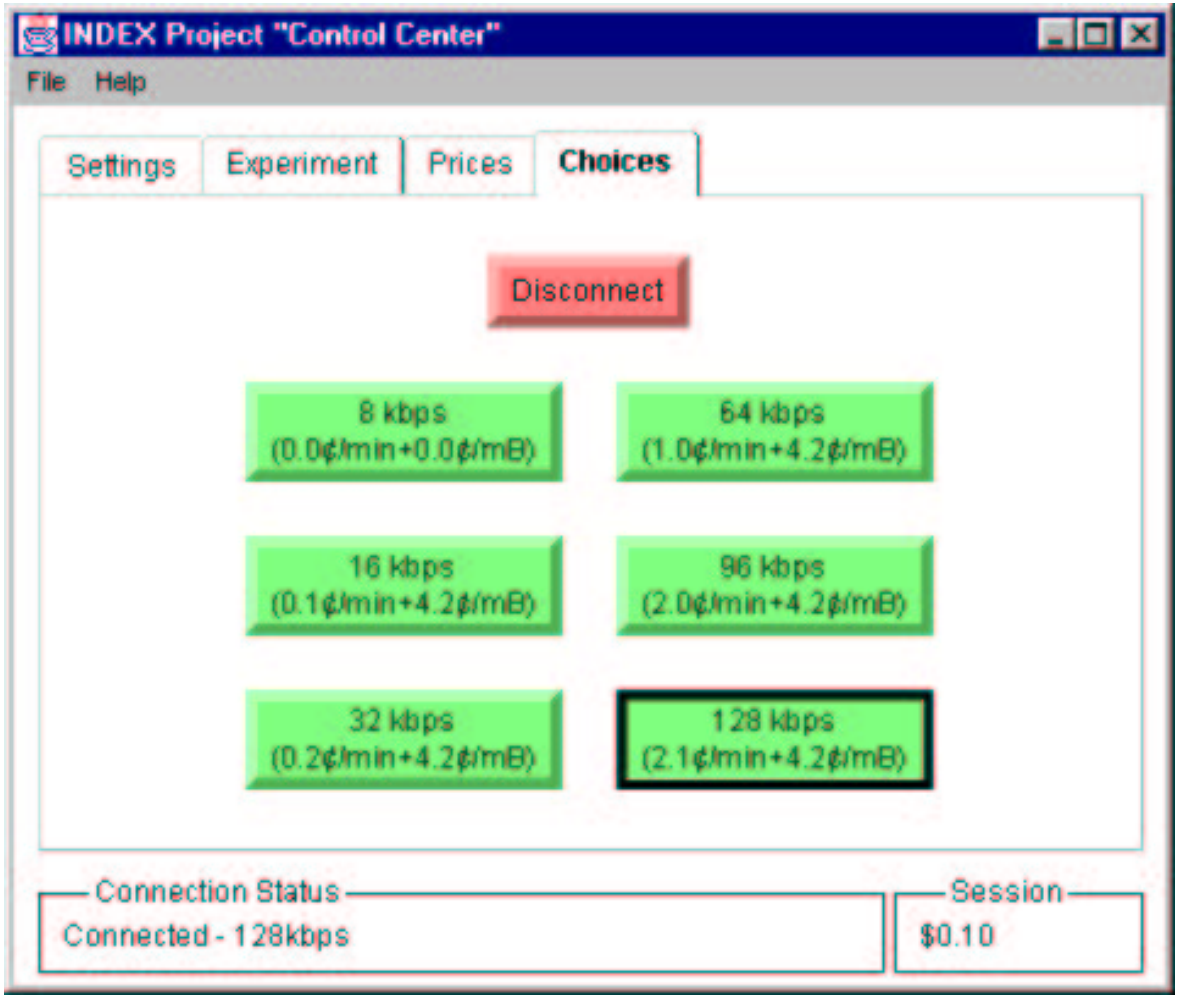
INDEX experiment

- Gave 70-80 Berkeley faculty, staff, and students 128Kbs ISDN service.
- We paid for equipment and sign up charges.
- We designed system so users could choose bandwidth whenever they wanted.
- 8Kbs, 16 Kbs, 32Kbs, 64Kbs, 96Kbs, 128Kbs.
- We changed the price menu for bandwidth every Sunday.
- We measured and analyzed the choices.
- Users paid *real money* and got the *actual bandwidth* they requested.

Technical design of INDEX



Bandwidth choice widget



Experiments run

Symmetric bandwidth. Users paid the same prices for upload and download.

Asymmetric bandwidth. Users paid different prices for upload and download.

Buyout pricing. Users were presented with a set of prices for bandwidth, and a rate at which they could buy out from the metered pricing. At the start of the week they could choose whether they wanted to face the metering or buy out.

Volume pricing. Users were charged for the cumulative bytes transferred over the course of the week.

Experiments run, continued

Fixed mixtures. Users were charged based on a weighted average of bytes transferred and bandwidth chosen, with the weights chosen by the experimenters.

Variable mixtures. Users were charged based on a weighted average of bytes transferred and bandwidth chosen, with the weights chosen by the users at the start of each week.

Subject characteristics

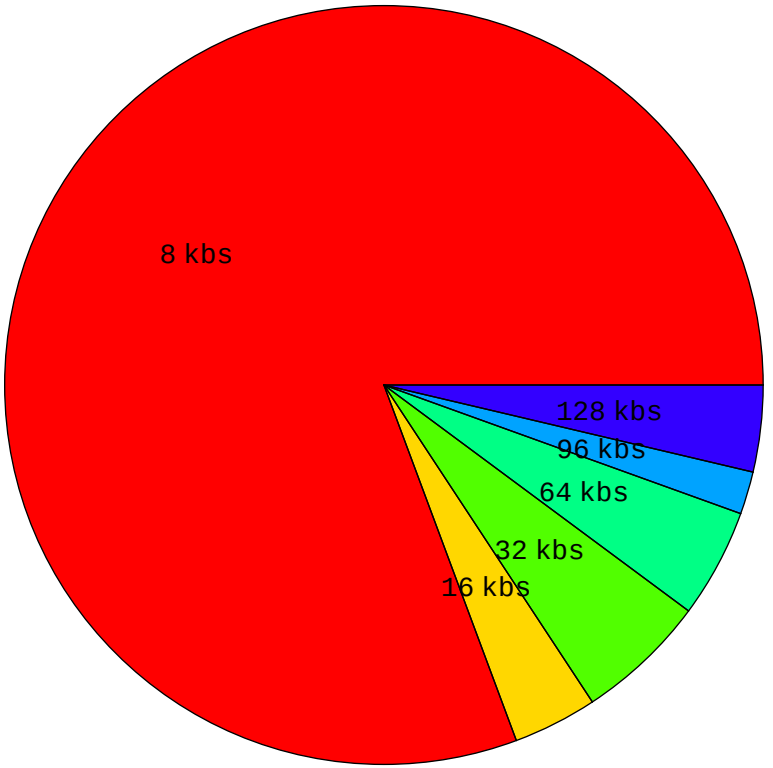
- Subjects recruited from UC Berkeley community.
- Tried for balance; demographic questionnaire.
- Subjects were volunteers.
- Average prices we charged were somewhat below market rates.
- Subjects *not* representative of population as a whole.
- But perhaps representative of “early adopters.”

Subject demographics

- Subjects were experienced and heavy users
  - 91% had used the Internet for more than 3 years
  - 86% had used computers for more than 5 years
  - 58% characterized their Internet use as “above average”
  - 56% considered themselves “computer profesionals”
- Age ranged from 20-72 years; average of 35
- Income somewhat higher than Nielsen average

Demand for bandwidth

- 8 Kbs free.
- Other bandwidths cost from .1 cent to 12 cents per minute.



Reduced form estimates

- Log-log regressions of minutes used on prices
- Zero usage omitted.
- No restrictions imposed.
- Significant coefficients in bold.

Bandwidth	p128	p96	p64	p32	p16
128	−2.0	+.80	+.25	−.02	−.16
96	**+1.7**	−3.1	**+.43**	+.19	+.18
64	+.77	**+1.8**	−2.9	+.59	+.21
32	+.81	−1.0	**+1.0**	−1.4	+.15
16	+0.2	−.29	+.04	**+1.2**	−1.3

Goodness of Fit

Bandwidth	With ISE	No ISE
128	.95	.11
96	.93	.25
64	.92	.18
32	.95	.14
16	.90	.17

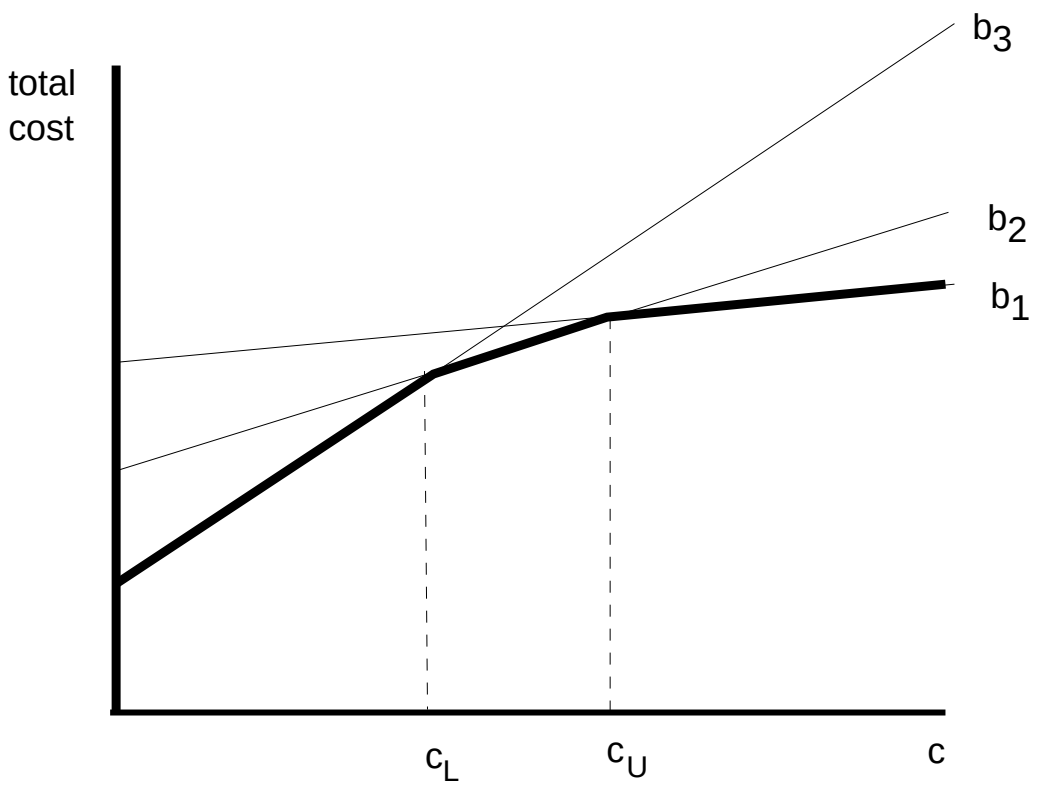
Structural estimates

- Utility depends on bits and time cost:
  $u(x) - [c + p(b^*)]t$
- Optimization:
  $u(x) - [c + p(b^*)]t \geq u(x) - [c + p(b)]t.$
- Bandwidth is bits per unit time, so $t = x/b$.
-

$$\min_{b^*<b} \frac{p(b^*)b - p(b)b^*}{b^* - b} \geq c \geq \max_{b^*>b} \frac{p(b^*)b - p(b)b^*}{b^* - b}.$$

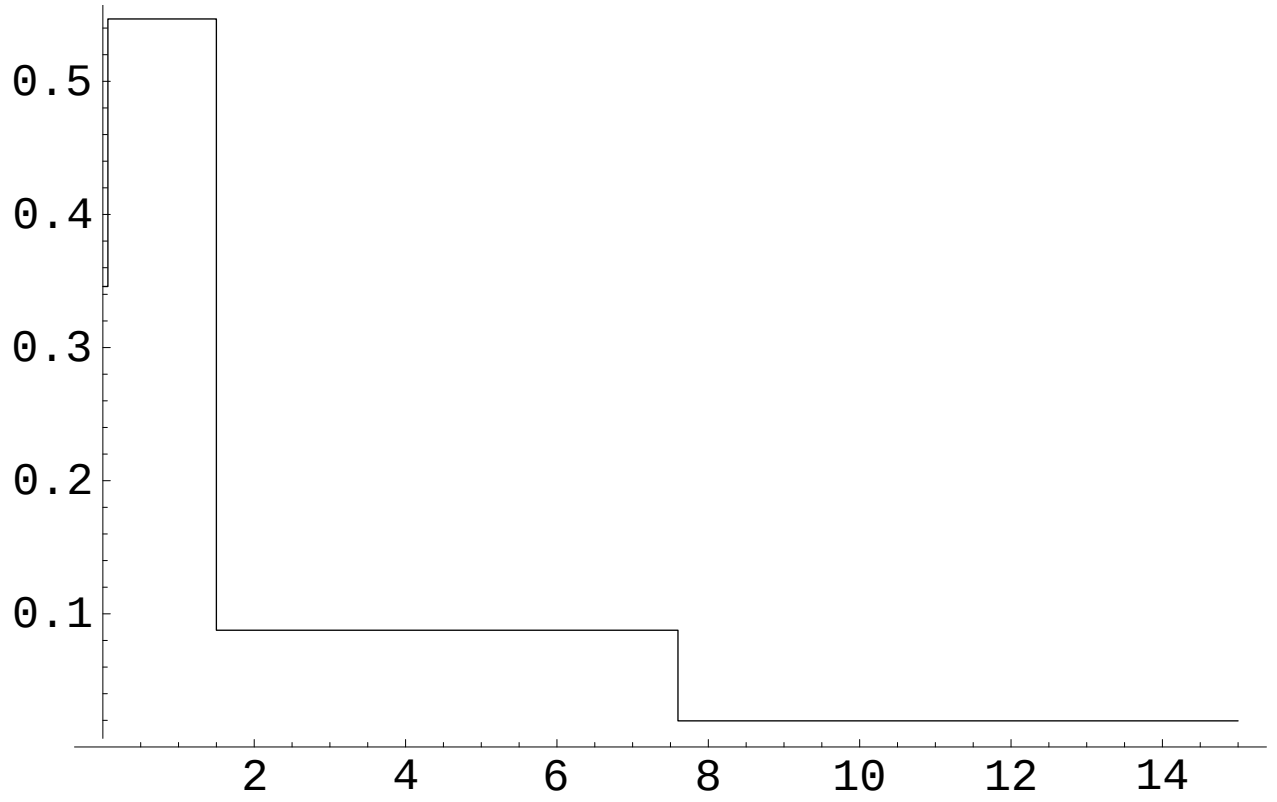
Graphical interpretation

$$\text{total cost of time} = K(c) = [c + p(b)]\frac{1}{b}$$



Estimating time cost

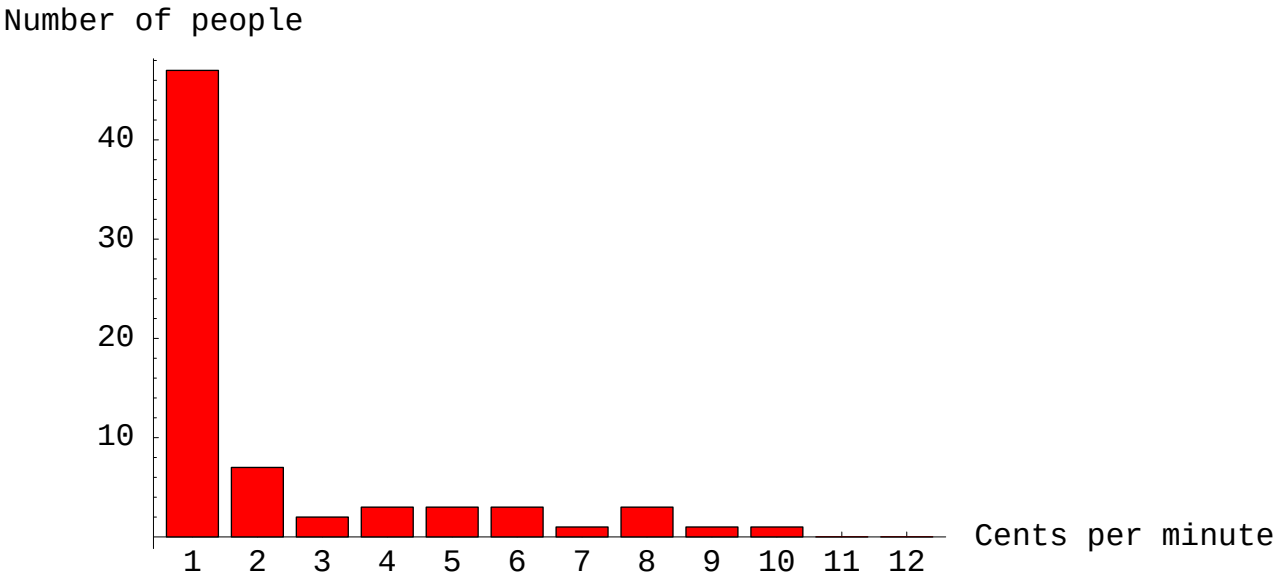
- Time cost is random parameter
- Observe frequency with which bandwidths are chosen and plot histogram.



Distribution of the time cost

Range	0	1	2	3	4	5	6	7	8	9	10
Up bound	39	8	3	4	1	2	2	1	2	0	3
Low bound	63	3	0	0	1	0	0	0	0	0	0
Average	47	7	2	3	3	3	1	3	1	1	0

Time cost distribution

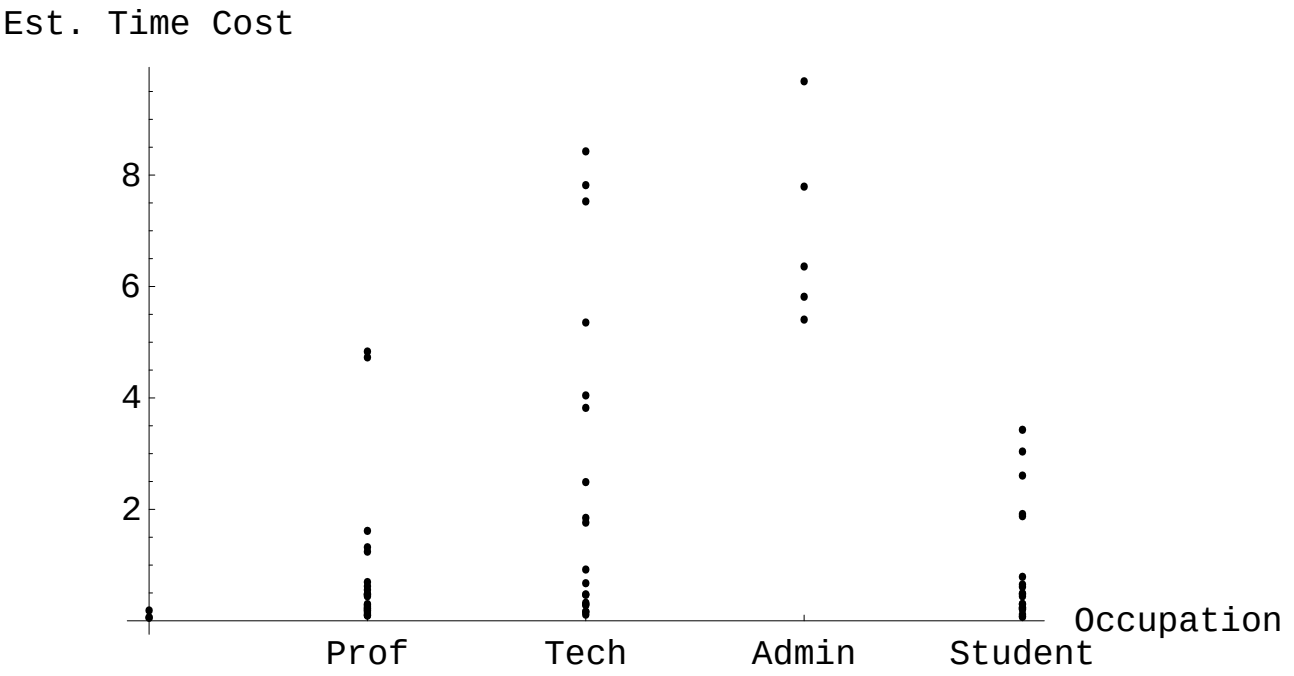


Who has high time cost?

$$\begin{aligned} c &= .86 \text{ professional} + 2.4 \text{ technical} \\ &+ 7.02 \text{ admin} + .91 \text{ student} \end{aligned}$$

- All coefficients are statistically significant.
- R^2 is $.646$.
- Adding "income" and "who pays" raises R^2 to $.652$.

Plot of time costs



Why is the time cost so low?

- Users are non-representative?
- Other uses of time?
- Service quality on rest of Internet?
- Can only measure value of existing applications?

Buyout pricing

- How much will people pay to avoid being metered?
- Each week prices were drawn in a range from $1 to $20 which measured the cost to the users of purchasing unlimited 128 Kbs usage.
- “Buyout fraction” = how much it cost to buy unlimited service up to and including other speeds.

Experimental design

Kbs	Cents per minute	Buyout fraction
16	.4	0.125
32	.8	0.250
64	1.6	0.50
96	2.4	0.75
128	3.2	1.00

Results of buyout experiment

- 40 subjects, 337 person weeks
- Buyout chosen 80% of time.
- 26% of the time subjects would have been better off with metering.
- Paid about a 50% premium to avoid facing metering.
- Volume transferred during bought out weeks = 11 megabytes per day.
- Volume transferred during the metered weeks = 1.25 megabytes per day.
- Revenue collected was higher during the bought-out weeks.

Summary

- Many users are not willing to pay much for higher bandwidth for today's applications.
- Administrative and technical users have significantly higher WTP.
- People will pay a substantial premium for unmetered pricing
- Unmetered pricing results in much larger demands on the system.

What should ISPs do?

- Encourage development of complementary applications.
- Sell to telecommuters.
- Engage in market segmentation by offering services that appeal to telecommuters such as:
  - Virtual Private Networks
  - Enhanced security
  - Online backup
  - Home office services